THE RECOVERY, RECONSTRUCTION, AND ANALYSIS OF YENİKAPI 14 (YK 14), A MIDDLE BYZANTINE MERCHANT SHIP FROM THE THEODOSIAN HARBOR EXCAVATIONS AT YENİKAPI, ISTANBUL

A Dissertation

by

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ABSTRACT

Since 2005, salvage excavations by the Istanbul Archaeological Museums associated with the Marmaray Project, a major expansion of the transportation infrastructure of Istanbul, Turkey, uncovered 36 Byzantine shipwrecks in the ancient Theodosian Harbor, one of the main port facilities of Byzantine Constantinople. At the invitation of the Istanbul Archaeological Museums, Cemal Pulak of the Institute of Nautical Archaeology at Texas A&M University directed the recording and recovery of eight of the Yenikapı shipwrecks between 2005 and 2008. This dissertation is an analysis and reconstruction of the hull of one of these ships, Yenikapı Wreck 14 (YK 14), dated to c. 900 C.E., based on extensive documentation and cataloging of the ship's surviving hull timbers between 2009 and 2013.

YK 14 was about 14.5 meters long and 3.5-4.0 meters in beam. It was built primarily of oak, probably in the Sea of Marmara region. Significant features include a nearly flat bottom, light scantling, and a relative lack of major longitudinal timbers in the hull. The hull was built using a combination of 'shell-first' and 'skeleton-first' construction methods: the hull planking was edge-fastened with wooden dowels called coaks from the keel to the waterline, a traditional 'shell-first' method, while the upper hull was built 'skeleton-first' using pre-erected frames to which the upper hull planking was fastened. The ship was in use for a number of years based on evidence of hull repairs, and was propelled with a single mast and lateen sail and steered with a pair of quarter rudders, a

typical configuration during the Byzantine period. Unlike some other Byzantine-era shipwrecks, YK 14's lightly-built hull may have been designed for short coastal voyages in the Sea of Marmara region rather than for open-sea voyages. YK 14 shows many similarities in construction and design to other Yenikapı ships dating to the ninth and tenth centuries, suggesting that it was typical of many vessels used in trade with the capital in this period. YK 14 is one of the latest known examples of the Mediterranean shell-based shipbuilding tradition, which was gradually being replaced by skeleton-first ship construction methods between 500 and 1000 C.E.

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The Institute of Nautical Archaeology's Yenikapı excavation team is grateful to current director Zeynep Kızıltan and former director Ismail Karamut of the Istanbul Archaeological Museums for the unparalled opportunity to work on the Yenikapı material. We would also like to thank assistant directors Rahmi Asal and Gülbahar Baran Çelik, excavation supervisors Sirrı Çölmekçi, Metin Gökçay, and Mehmet Ali Polat, as well as archaeologists Ülkü Başrak, Bariş Mirzanlı, Seda Ülger, and the many museum staff members and archaeologists at Yenikapı who assisted in the recovery and study of this shipwreck and supported our efforts at Yenikapi. Sadık Demir of İmge Harita İnşaat graciously supplied his time, staff, and total station equipment for the mapping of the shipwrecks.

I am grateful to my committee chair, Cemal Pulak, for a decade of opportunities for archaeological work in Turkey, including the once-in-a-lifetime experience of working on the Yenikapı shipwreck excavations between 2005 and 2008 and researching the YK 14 shipwreck for my dissertation; I have benefited from his knowledge and advice at every stage of the research and writing process. I would like to thank my committee members for their thoughtful comments and advice during various stages of this project, and for reading a long dissertation in a short period of time. In addition to my dissertation committee members, several of my professors in the Nautical Archaeology Program and the Anthropology Department at Texas A&M University have also contributed to my research, including Vaughn Bryant, Kevin Crisman, and Donny Hamilton. I am particularly grateful to the professors who supplied recommendations for the grants that funded this project.

Financial support for this research was provided by the Institute of Nautical Archaeology (INA); the American Philosophical Society's Lewis and Clark Fund for Exploration and Research; and the College of Liberal Arts, the Department of Anthropology, the Office of Graduate Studies, and the Melbern G. Glasscock Center for Humanities Research at Texas A&M University.

YK 14's excavation and recovery in 2007 required five months of difficult work by INA archaeologists and staff in what proved to be an exceptionally hot summer in Istanbul. The excavation team in 2007 included Korhan and Murat Bircan, Mehmet Çiftlikli, Rebecca Ingram, İlkay İvgin, Sheila Matthews, and Asaf Oron. Sheila's RHINO tutorials in Bodrum as well as her initial work in mapping the shipwreck and advice on timber cataloging were instrumental for this project. Ilkay more or less single-handedly constructed nearly every wooden timber mold used to support the large number of curved hull planks removed from the ship.

This project would not have been possible without major logistical as well as financial support from the Institute of Nautical Archaeology, especially for the use of the Bodrum Institute's dormitories and research facilities, and the assistance of the institute's staff, all of whom contributed to the successful completion of this project. I am indebted to the INA Bodrum Research Center's former director Tufan Turanlı and current director Tuba Ekmekçi for dealing with many of the bureaucratic complexities of the Yenikapı project and for their invaluable assistance during my time in Bodrum.

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CHAPTER I

INTRODUCTION: THE THEODOSIAN HARBOR EXCAVATIONS AT YENİKAPI, ISTANBUL, AND THE MARITIME TRADE OF CONSTANTINOPLE FROM THE FOURTH TO THE ELEVENTH CENTURY C.E.

1) Introduction

In late 2004, archaeologists of the Istanbul Archaeological Museums began a salvage excavation in the Yenikapı district of Istanbul, Turkey, located near the southern Sea of Marmara shore of the old city. The excavations are part of the Marmaray Project, a multi-billion dollar expansion of northwest Turkey's transportation system, which will include the construction of new subway stations in the city of Istanbul and its suburbs, an expansion of the suburban rail line, and the Marmaray Tunnel, a rail tunnel under the Bosporus Strait that will connect the European and Asian sides of the city.[1] The Yenikapı site is the largest of the construction areas, comprising approximately 58,000 square meters (**Figure 1.1-2**).[2] The Yenikapı excavation area will include a metro station as well as access to the State Railways and suburban rail line through to the Bosporus Tunnel.[3] Under the directorship of İsmail Karamut and Zeynep Kızıltan, the excavation at Yenikapı has uncovered a vast array of archaeological finds from the city's history, ranging from 8,000-year-old Neolithic dwellings, footprints, and cremation and

[1] Özmen 2007; see also Çelik 2010; Eyigün 2010. The depth of the tunnel is 56 meters below sea level, making it the deepest underwater tunnel in the world (DLH Marmaray Division Directorate, March 2011).
[2] Kızıltan 2007; 2010; see also Gökçay 2007b; 2007c; Eyigün 2010, 54-5.
[3] Gökçay 2007a; 2007b; Asal 2007; Asal 2010.

inhumation burials, classical amphoras and sculptures, a Byzantine church, and Ottoman-era paved roads, workshops, and cisterns.[4] Perhaps the most significant discoveries, however, are from the ancient Theodosian Harbor, the largest commercial harbor serving the late Roman and Byzantine capital of Constantinople between the late fourth and eleventh centuries.[5] In addition to the remains of ship cargoes and refuse dumped in the harbor, harbor installations built of stone, wood, and concrete, and loose ships' timbers and items of ships' equipment such as anchors and rigging elements, at least 36 shipwrecks have been found in the excavation area.[6] These shipwrecks represent the largest collection of ancient and early medieval vessels ever found in the Mediterranean at a single site, and include the best preserved Byzantine ships yet discovered.

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[4] Kızıltan 2007; 2010; see also Gökçay 2007c; Asal 2010; Kocabaş 2010; 2012.
[5] Mango 1993, 121.
[6] The number of shipwrecks includes well-preserved, articulated hull remains and excludes disarticulated ship timbers that could not be immediately associated with a particular shipwreck. The disarticulated timbers from the site include a number of keel timbers, which indicate that the total number of vessels of all sizes found in the Yenikapı excavation area is higher than the current count of 36. A more accurate estimate of the total number of vessels represented by the hull remains at the site will require a detailed study of the recovered disarticulated remains, but it is likely that the total number of shipwrecks, including small craft, may be over 50.

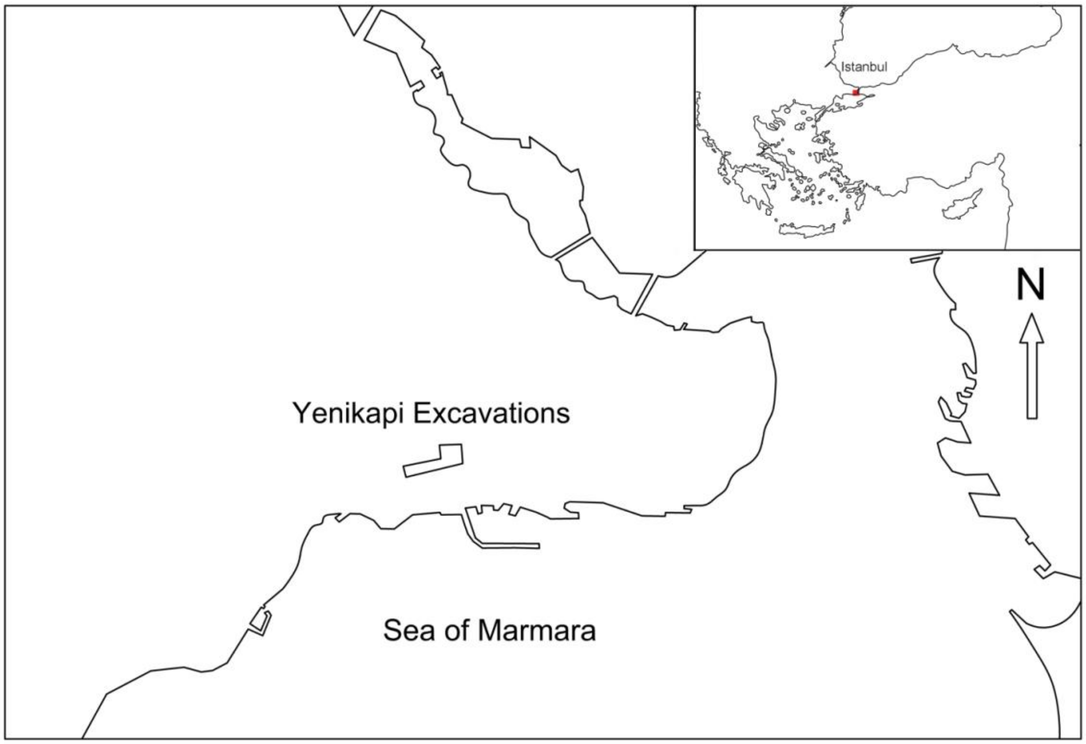

Figure 1.1: Location of the Yenikapı excavations in the center of Istanbul's Old City (Adapted from Google Maps).

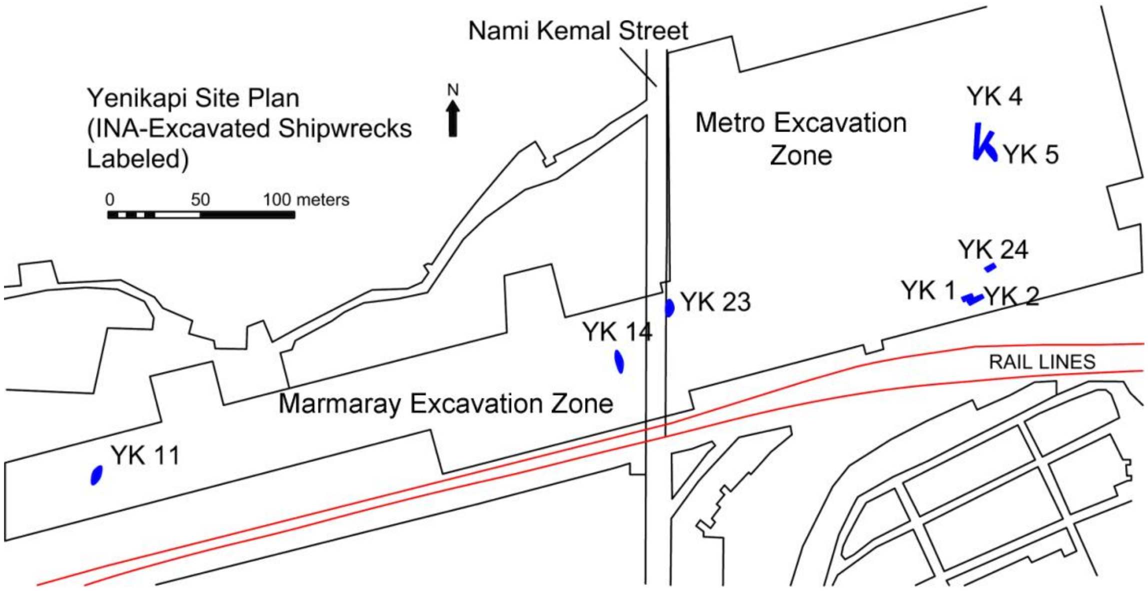

Figure 1.2: Shipwrecks documented by INA from the Yenikapı site (Adapted from Kocabaş 2008, 184-85, and Gökçay 2010, 135, Fig. 1).

The first two shipwrecks discovered on the site, YK 1 and 2, were found during the spring of 2005.[7] In June of that year, the director of the Istanbul Archaeological Museums, İsmail Karamut, invited Cemal Pulak of the Institute of Nautical Archaeology (INA) at Texas A&M University to document and dismantle the shipwrecks. Eventually, Pulak and his team recovered eight shipwrecks in all between 2005 and 2008 (Table 1.1):[8]

[7] Shipwrecks from the site were given 'YK' abbreviations for Yenikapı, and numbers based on their order of discovery. During the excavation, shipwrecks were also separately numbered based on the find areas, which were either in the Marmaray Tunnel excavation area (numbered MRY 1, 2, etc.) or the Metro area (Metro 1, 2, 3, etc.), the site of a future metro station being constructed under the supervision of the Fatih Municipality; thus all 36 shipwrecks on the site have two numbers (e.g., example YK 14/MRY 7). For the sake of brevity, only the YK numbers are used to refer to Yenikapı shipwrecks in this study.

[8] The Institute of Nautical Archaeology's excavation team for the documentation and dismantling of eight Yenikapı shipwrecks included Director Cemal Pulak, Assistant Directors Sheila Matthews and Robin Piercy, and archaeologists, conservators, and Bodrum Research Institute staff members, including Yasemin Aydoğdu, Korhan Bircan, Murat Bircan, Can Ciner, Emrah Çankaya, Mehmet Çiftlik, current

Table 1.1. Yenikapı shipwrecks studied by Cemal Pulak and the Institute of Nautical Archaeology (INA)

Number	Date	Type	Estimated length	Primary wood type(s)[9]	Date of excavation
YK 1	Late tenth century	Merchantman	10 m	*Quercus cerris*	August 2005-January 2006
YK 2	Late tenth century	Galley	30 m	*Pinus nigra, Platanus orientalis*	April-August 2006
YK 4	Late tenth century	Galley	30 m	*Pinus nigra, Platanus orientalis*	September 2006-April 2007
YK 5	Late tenth century	Merchantman	14.5 m	*Quercus cerris*	March-September 2006
YK 11	Late sixth-early seventh century	Merchantman	11 m	*Pinus brutia*	May 2008-November 2008
YK 14	Late ninth-early tenth century	Merchantman	14 m	*Quercus cerris*	April-September 2007
YK 23	Late eighth-early ninth century	Merchantman	15 m	*Quercus cerris*	December 2007-May 2008
YK 24	Late tenth century	Merchantman	8 m	*Quercus cerris*	July-August 2007

The initial excavation of the shipwrecks and the documentation and recovery of artifacts found around the shipwrecks was undertaken by the Istanbul Archaeological Museums' archaeologists, while teams from INA/Texas A&M University and Istanbul University were responsible for the in-situ documentation and dismantling of the shipwrecks, with additional assistance from the staff of the Archaeological Museums and Marmaray

Bodrum Research Center (BRC) director Tuba Ekmekçi, Funda Genç, Rebecca Ingram, İlkay İvgin, Michael Jones, Sarah Kampbell, Gülser Kazancıoğlu, Orkan Köyağasıoğlu, Matthew Labbe, Ryan Lee, INA Head Conservator Asaf Oron, Evren Turkmenoğlu, and Seda Ülger. Sadık Demir and a surveying team from İmge Harita İnşaat mapped the eight shipwrecks in collaboration with Sheila Matthews. Wood species identifications are by Nili Liphschitz of Tel Aviv University. The information in Table 1.1 was previously published in Liphschitz and Pulak (2009) and Ingram and Jones (2010).

[9] Wood identification was carried out by Nili Liphschitz of the Institute of Archaeology, Botanical Laboratories, at Tel Aviv University (see also Liphschitz and Pulak 2009).

Project construction contractors.[10] Four of the tenth-century ships, including two merchantmen, YK 1 and YK 5, and two galleys, YK 2 and YK 4, have been documented by Pulak's team in Istanbul, and will be conserved by Istanbul University's Department of Conservation of Marine Archaeological Objects. Four of the dismantled merchantmen, including a seventh-century merchant vessel (YK 11), an early ninth-century ship (YK 23), YK 14 (the topic of this dissertation), probably dating to the ninth or early tenth century, and a tenth-century ship (YK 24) are now housed at the Nixon Griffis Conservation Laboratory at the Institute of Nautical Archaeology's Bodrum Research Center (BRC), where their documentation and conservation has been underway since 2009. The remaining 28 shipwrecks discovered at the site were recovered by a team from Istanbul University directed first by Sait Başaran, and later by Ufuk Kocabaş, between 2006 and 2012.[11] After conservation, a number of the ships will be reassembled and displayed in Istanbul in a planned museum.[12]

Most of the Yenikapı shipwrecks were found on the eastern end and the central section of the site. The earliest hull remains from the site date to the fifth century C.E., while the majority date from the Middle Byzantine period, from the seventh to late tenth or early

[10]Although the most of the ships were found without cargo and appear to have been salvaged in antiquity, at least three wrecks (YK 1, 12, and YK 35) were discovered with much of their original amphora cargoes in situ (Pulak 2007a, 208-11; 2007b, 106-7; see also Kocabaş 2008; 2010; Istanbul Archaeological Museums, www.istanbularkeoloji.gov.tr). These vessels seem to have been covered by layers of sand quickly and their locations forgotten before their cargoes could be fully salvaged. In addition, many of the shipwrecks contained artifacts that were apparently missed during the salvaging of the shipwrecks, or were accidentally dropped or discarded from other vessels.
[11] Kocabaş 2012a.
[12] Asal 2010, 29.

eleventh centuries.[13] YK 14 was discovered in the approximate center of the excavation just to the west of Namik Kemal Street and to the north of the Turkish State Railways (TCDD) and Suburban (Banliyö Trenleri) rail station and the Güneşler bus station.

The significance of the Yenikapı finds must be understood in the context of Constantinople's role in the late antique and early medieval Mediterranean. Between the fourth to the twelfth century, Constantinople was the political and cultural capital of the Eastern Roman (and later, Byzantine) Empire as well as one of the main economic centers of the Mediterranean.

2) The Theodosian Harbor and the Maritime Trade of Constantinople, 330-1025 C.E.

In choosing Byzantium as the site of a new capital for the Roman Empire in the early fourth century C.E., Constantine I (324-337) may have intended to avoid some of the problems presented by the location of Rome as an imperial capital. Although the Romans had fully conquered the Mediterranean basin by the later first century B.C.E., Rome itself presented some difficulties as a capital for a Mediterranean-wide empire, with a population of between 500,000-1,000,000 residents by the early imperial period.[14] The city was situated at the lowest crossing of the Tiber, a strategic position on the Italian peninsula, but was too far upriver for seagoing ships. During the Republican and

[13] Pulak 2007a, 203. In this study, the Middle Byzantine period is defined as beginning in the reign of Heraclius (610) and ending with the capture of Constantinople in the Fourth Crusade (1204). This division is proposed by Mango (2002, 5; 2005, 1) and roughly correspond to those followed by other scholars (e.g., Jones 1964; Whittow 1998; Haldon 2005). For a detailed discussion of chronological divisions of the Byzantine period, see Shepard 2008a.
[14] Van Dam 2010, 9, n. 5.

Early Imperial periods, maritime imports for Rome were transported to the port of Ostia at the mouth of the Tiber. Ostia could not accommodate large ships and had a recurring silting problem; the cargoes of large ships were therefore unloaded into smaller, shallow-draft lighters, which were towed upstream to Rome or to warehouses lining the Tiber outside of the city.[15] The lack of significant harbor facilities for large ships, combined with Early Imperial Rome's enormous demand for grain and other goods resulted in the construction of Portus, a massive artificial harbor begun in 42 C.E. by the emperor Claudius (41-54) and expanded by Trajan (98-117) early in the next century.[16] Furthermore, Rome's access to the sea faced west, away from the richer and more populous eastern half of the empire and from Egypt, which supplied much of the grain used to feed the city.[17]

During the third century C.E., Roman emperors began to look for alternative capitals to Rome. The third century was a period of frequent civil wars, economic instability, and incursions by the empire's enemies.[18] By this time, most of the empire's military forces—the main basis for imperial power—were located along the empire's frontiers, and the role of the Roman Senate in government declined in favor of often rebellious army officers.[19] The emperor Diocletian (285-305) responded to challenges in governing the empire by dividing its administration into eastern and western halves, each ruled by

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[15] Mango 2000, 192; see also Toynbee 1973, 207.
[16] Casson 1995, 369; see also Shaw 1972, 98. Based on contemporary references to amounts of grain imported to Rome in the first century B.C.E. and first century C.E., Casson (1980, 21-3; 1995, 369) estimates that 400,000-500,000 tons were imported annually.
[17] Toynbee 1973, 207; see also McCormick 2005, 112; Goldsworthy 2009, 381-83; Haldon 1990, 16.
[18] Goldsworthy 2009, 134-53; see also Ostrogorsky 2007, 29-37.
[19] Goldsworthy 2009, 161-73; see also Jones 1964, 1:687.

an ‘Augustus’ with his own separate capital, army, and bureaucracy.[20] The capitals of each half of the empire frequently shifted. Successful emperors in this period tended to campaign frequently with their loyal soldiers and stay in provinces where they had strong support, a pattern followed by the emperor Constantine I; effectively the capital was wherever the emperor and his army and court were.[21] In the east, imperial capitals following the reign of Diocletian included Thessalonica, Nicomedia, Nicaea, and, eventually, Constantinople.[22]

Constantine decided on the site of Byzantium for his capital in 324 and inaugurated the city six years later.[23] According to Herodotus, this location had been noticed as early as the sixth century B.C.E. as a fine location for a port city.[24] In the second century B.C.E., the Greek historian Polybius described the natural advantages of the site of Byzantium for regulating and engaging in maritime trade:

> The position of Byzantium in relation to the sea affords greater advantages for its security and prosperity than that of any other city in our quarter of the world, but in relation to the land the situation is the exact opposite. On the seaward side it commands the entry to the Black Sea so completely that no one can sail in or out without the consent of the Byzantines. The result of this is that they exercise absolute control over the supply of those numerous products which the rest of the world requires for its everyday life, and in which the Pontus is particularly rich. As regards the necessities of life, there is no disputing the fact that the lands which surround the Pontus provide both cattle and slaves in the greatest quantities and of the highest quality; and as for luxuries, the same regions not

[20] Runciman 1966, 21-5; Treadgold 1997, 15-27.
[21] Mango 1993, 119; Goldsworthy 2009, 162-63; van Dam 2010, 24-9, 47-8.
[22] Crow 2001, 90-3; Magdalino 2010, 51.
[23] Runciman 1966, 14.
[24] *Hdt*. IV.144; see also Toynbee 1973, 206-8. Polybius also notes that the currents are more favorable to sailing to Byzantium rather than Chalcedon on the other side of the Bosporus (*Polyb*. 4.44).

> only supply us with honey, wax, and preserved fish in great abundance, but they also absorb the surplus produce of our own countries, namely olive oil and every kind of wine. In the case of corn there is a two-way traffic, whereby they sometimes supply it when we need it, and sometimes import it from us… It is, no doubt, the Byzantines themselves who draw the greatest financial benefit from the location of their city, since they can easily export all their surplus produce and import whatever they need at a profit to themselves…[25]

Although the role of trade with the Black Sea had changed since the Hellenistic period and was less significant by late antiquity, the site of Byzantium was ideal for controlling east-west land traffic as well as north-south sea traffic. Constantinople was closer than Rome to the major population centers of coastal Asia Minor and the Levant, and was adjacent to the rich agricultural land of Thrace.[26] Its position in relation to the sometimes unstable northern and eastern borders of the empire also allowed emperors to respond to military threats from these quarters in a more timely fashion than was possible from Rome.

Byzantium's rededication as Constantinople was intended to establish the city as a permanent capital on the scale of Rome in the early Empire. Roman civic institutions and public facilities such as a new imperial senate, baths and a hippodrome for games were duplicated in Constantinople; the city was planned to be a metropolis

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[25] *Polyb*. 4.38 (trans. Shuckburgh 1962). The role of the Black Sea trade in the late Roman and Byzantine periods was somewhat different than that described by Polybius in the second century BC. In the tenth-century *De administrando imperio*, the author describes the inhabitants of Cherson as living by exporting hides and wax obtained in trade with the Pechenegs to Byzantine territory, In the case of a Chersonite rebellion, the author recommends imposing an embargo on shipping "grain, wine, and other needful commodities or merchandise" from the northern coast of Asia Minor to Cherson and imprisoning Chersonite merchants in Constantinople and impounding their ships and cargoes (Moravcsik and Jenkins 2008, 287). This account seems to indicate that Cherson in the tenth century was a relatively small trading community rather than a major grain exporter, probably because the Pechenegs did not encourage agriculture in the regions under their control (Toynbee 1973, 213; see also Mango 1993, 118-19).
[26] Jones 1971, 2-3; see also Hendy 1985, 46-54, 90-100.

approximately the same size as Rome, which may have been inhabited by up to a million people at its height.[27] Because it was the residence of the emperor, residence in Constantinople became compulsory for senators and many imperial officials as well; over time, it also became the center of the Orthodox Church, and, as a result, a major repository of saints' relics and one of the most important pilgrimage destinations in the Mediterranean.[28] Besides the economic opportunities presented by an expanding city full of high-ranking officials and their retinues, incentives were also given by the imperial government for citizens to relocate to the new capital, including bread allowances for up to 80,000 new settlers who built a house in the city.[29] Many citizens traveled to the capital for the settlement of legal disputes, while others, including many bishops from provincial areas, preferred to live in the capital because it was the center of political power and cultural life of the empire.[30]

Fundamental additions to the new capital city included expansion of the infrastructure for food, water supplies, and defense. Constantine had a larger circuit of walls built for the city in the 320s;[31] by the 390s, the city had grown so much that a new and much larger circuit of land walls was begun by Theodosius II (**Figure 1.3**).[32]

[27] Jones 1964, 1:688; see also Goldsworthy 2009, 42.
[28] Carr 2001; see also Wortley 1999.
[29] Jones 1964, 2:688, 697; see also Pharr 1952, 418-19; Mango 1985, 37.
[30] Jones 1964, 2:688-89; see also Toynbee 1973, 214, 222-23; Magdalino 2010, 43-4, 50-4; Ward-Perkins 2000.
[31] Mango 1993, 118; see also Toynbee 1973, 216-17. The foundations of this wall seem to have been found at the western end of the Yenikapı excavations (Gökçay 2007a, 172-73).
[32] Crow 2007, 262.

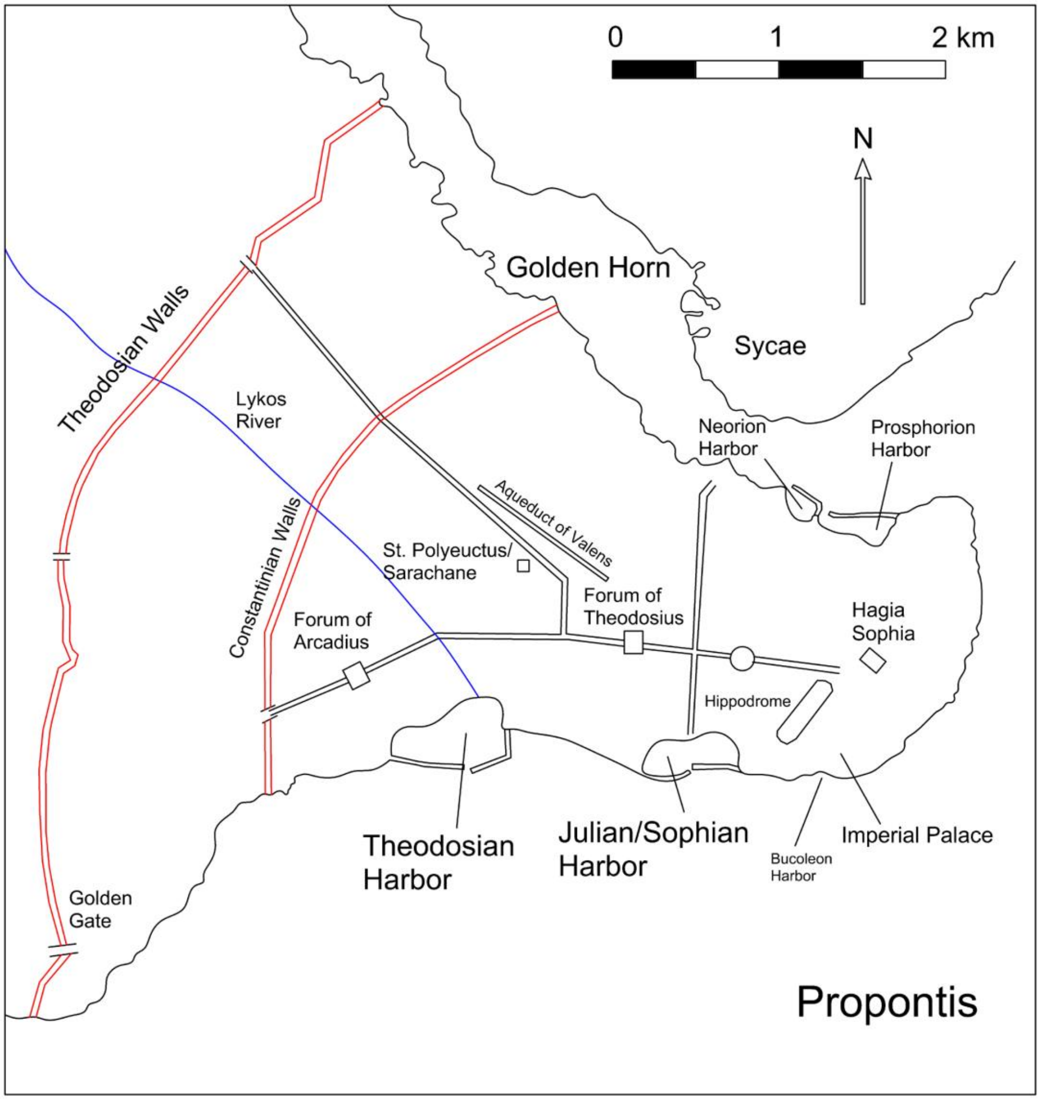

Figure 1.3: Map of Constantinople in the early Byzantine period (After Mango 2002, 64; Müller-Wiener 1977, 18, Abb. 38; and Treadgold 1997, 674).

The Theodosian Walls, begun three kilometers west of Constantine's walls in 412, were exceptionally strong defensive works consisting of three lines of curtain walls punctuated by towers and with a large moat between the first and second walls. They were one of the most formidable fortification systems of any city in the ancient world, and were never breached by an attacking army until 1453.[33] Such strong defenses were necessary. Although the city was situated on a peninsula, there were no major obstacles to attack on the landward side, and the city's hinterland, as well as most of the region of Thrace, has few natural barriers to invasion. Polybius noted the city's vulnerability to attack by Thracian tribes, and during the Late Roman and Byzantine periods foreign invasions were relatively frequent.[34] In the first decade of the sixth century, the emperor Anastasius began an outer defensive line known as the Anastasian or Long Walls of Thrace 60 km west of the city. While this defensive line stopped some incursions, it was too long and too expensive to be fully manned and served more as an early-warning system to warn the capital of attack than as a true defensive barrier.[35] More often attackers were stopped only at the walls of the city.[36]

The site of Constantinople is also lacking in fresh water supplies vital for a city of several hundred thousand. Several springs and the sluggish Lykos River flowed within the city walls, but much more water was needed, especially for the baths and public fountains considered necessary in a Late Roman city; contemporary accounts from the fourth through sixth centuries mention water shortages, particularly in the summer and in

[33] Lawrence 1983, 180-84; see also Croke 2005, 61, 63; Tsangadas 1980; Crow 2002, 92; 2007, 262-68. The successful Crusader attack on the city in 1204 was directed at the sea walls along the Golden Horn (Treadgold 1997, 666).
[34] *Polyb*. 4.45; see also Mango 2002, 66-8.
[35] Crow and Bayliss 2004, 30; see also Crow 1995; Crow 2002, 344-45; Croke 2005, 60; Toynbee 1973, 217.
[36] Toynbee 1973, 217-8; see also Mango 2002, 66-8.

periods of drought.[37] Hydraulic engineers began construction of a new aqueduct system in the fourth century to supply the city, which was modified and expanded over the next two hundred years; archaeological surveys have determined that it is the longest known aqueduct system from the Roman Empire.[38] Unlike Rome's aqueducts, which tapped one main source of water, Constantinople's aqueducts were a dendritic system stretching over 592 km, with a main branch heading west into Thrace and a smaller northern branch into the Belgrade Forest near the Black Sea.[39] An extensive network of at least 150 large open-air and covered cisterns were also constructed in the city in the fifth and sixth centuries, both for everyday needs and as a security measure to ensure an adequate water supply in the city during droughts and sieges.[40] Aside from the period between the siege of 626, when the Avars cut the main aqueduct line, and 765, when Constantine V restored it, the aqueduct system apparently functioned continuously until the reign of Manuel Komnenos (1118-1180); recent archaeological surveys recorded abundant evidence of Middle-Byzantine period repair work on the aqueducts.[41]

As in Rome, the imperial authorities took great care to ensure adequate food supplies in the capital, especially to avoid civil unrest which could threaten those in power.[42] Imperial warehouses held the supplies for the *annona*, a state-sanctioned allotment of

[37] Crow and Bayliss 2004, 29, 46; see also Mango 1995, 13; Croke 2005, 68-9.
[38] Crow et al. 2008, 1; see also Crow and Bayliss 2004, 39, 33-8, 46; Crow 2007, 271-79; Mango 1995, 13.
[39] Crow et al. 2008, 1, 25-87.
[40] Croke 2005, 62, 68; see also Crow and Bayliss 2004, 31; Crow 2007, 269-79; Toynbee 1973, 215-16.
[41] Crow and Bayliss 2004, 38, 45-47. According to Crow and Bayliss (2004, 45-6), the smaller, aqueduct of Hadrian likely continued to function between the Avars' cutting of the main aqueduct of Valens in 626 and Constantine V's repair of the same aqueduct in 765/766.
[42] Teall 1959, 91; see also Toynbee 1973, 203, 205.

food for a large portion of the city's population, particularly government employees and the poor, while the remainder of the population was fed through local produce and imports by independent private merchants.[43] *Annona* rations, which were in the form of baked bread by the Late Roman period, were distributed on 'steps' (*gradus*) or terraces to recipients with bronze tickets.[44] The *annona* began in Rome under Augustus as a grain ration, although corn distributions to the public as well as price controls had been common in Greek cities of the Hellenistic period and are attested in Rome starting in 123 B.C.E.[45] By the third century C.E., *annona* rations consisted of baked bread and also included wine, olive oil, and sometimes other foods.[46] When the capital was moved to Constantinople, *annona* shipments were sent there as well. The state also maintained a reserve fund for purchasing grain for the city's inhabitants in case of famine.[47] In Constantinople, structures related to feeding the city included harbor facilities, state-owned warehouses (*horrea*), state-run bakeries (*pistrina publica*), which supplied much of the city's bread, and open spaces and buildings used for public markets. Archaeological work in Istanbul and surviving textual sources, particularly the *Notitia Urbis Constantinopolitanae*, a list of the city's major buildings composed after 425

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[43] Mango 2000, 190; see also Rickman 1980, 201.
[44] Pharr 1952, 418; see also Mango 2000, 194; Crow 2007, 256-57.
[45] Rickman 1980, 156-97.
[46] Grain rations were replaced by baked bread in the reign of Aurelian, who also started a seasonal pork ration with the *annona* in Rome (Rickman 1980, 187, 206-7; see also Jones 1964, 2:696, 702-3; Mango 2000, 190; Pharr 1952, 549-50). Oil was included in the *annona* by the reign of Septimius Severus, and in Rome was dispensed in small shops (*mensae olearia*) that were probably owned by the state; the state also sold wine (Jones 1964, 2:701, 704). Other products that may have been included in *annona* rations are lard, legumes, dried fruits, and olives (Koder 2002, 113-15; see also Jones 1964, 2:695; Mango 2000, 190.
[47] Jones 1964, 1:698; see also Geanakoplos 1986, 250-51.

during the reign of Theodosius II, give some idea of these features in Constantinople's early period as a capital city.[48]

Most of Constantinople's food supplies arrived by sea.[49] C. Mango estimates that the capital required between 2,400 and 3,600 ships to carry grain for the city each year based on a sixth-century grain import figure.[50] During the fourth century, four major commercial harbors were constructed or expanded in Constantinople, with an estimated four to five kilometers of wharves on the Golden Horn and the Sea of Marmara sides of the city.[51] The Neorion and Prosphorion harbors were established on the north shore of the city on the Golden Horn in modern Istanbul's Sirkecı neighborhood. The Neorion harbor functioned as a commercial harbor until the reign of Justinian, when it was converted to military uses.[52] Two commercial harbors were also excavated from natural indentations along the southern Marmara coast, in large part for importing food supplies and the construction materials necessary for the capital's expansion.[53] The Julian Harbor, estimated to have been about 600 m in diameter, was located in Istanbul's modern

[48] Mango 2000, 189-90, 192; see also Jones 1964, 1:689.
[49] Mango 2000, 192-93. Diocletian's Price Edicts, an attempt by the emperor to regulate prices of goods and services throughout the empire, lists shipping costs for grain by sea vs. on land. According to one calculation, "It was cheaper to ship grain from one end of the Mediterranean to the other than to cart it 75 miles" (Jones 1964, 2:841-42). Although Jones' calculation has been challenged, and the extent to which the prices in the Edict accurately reflect prices in the early fourth century is still debated, there is universal agreement that sea transport was significantly cheaper and faster than land transport (Duncan-Jones 1982, 366-69).
[50] Mango 1993, 120.
[51] Mango 1993, 120; see also Tsangadas 1980, 54-8.
[52] Magdalino 2007, 20, 94-5. Mango estimates these harbors as having a combined width of 700 m (Mango 1993, 120). There were probably smaller anchorages in the area, or the Neorion harbor was larger than previously thought, based on the discovery of Late Roman quays in the vicinity as well (Dark 2004a; 2004b).
[53] Mango 1993, 120-21; see also Tsangadas 1980, 53-4.

Kumkapı district.[54] It was also known as the Sophian Harbor after a renovation by emperor Justin II in the later sixth century, who re-named it after his wife.[55] A small harbor later known as the Bucoleon Harbor was also built to the east of the Julian Harbor to serve the royal palace.[56]

Further west in the modern neighborhood of Yenikapı, the Theodosian Harbor, or *Portus Theodosiacus*, was begun under emperor Theodosius II some time after 390.[57] The harbor has been associated with the older Eleutherian Harbor on the city's southern coast, but this harbor was probably further to the east.[58] In 673, when Theophanes records the assembly of warships in the harbor to repel an Arab fleet, it was also called the Harbor of Kaisarios.[59] The Theodosian Harbor was constructed at the mouth of the Lykos River, at the site of a deep natural bay to the northwest of the modern Yenikapı ferry terminal.[60] The harbor consisted of an excavated harbor basin fortified with walls

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[54] Mango 1993, 121; see also Janin 1964, 231-34; Guilland 1969, 80-3, 87-91.
[55] Mango 1993, 121. In the later Byzantine period the Julian-Sophian Harbor was called the *Kontoskalion* and was used as a harbor for the Byzantine war fleet, a use that continued under the Ottomans, who renamed it the *Kadırga Limanı* ('galley harbor') (Müller-Wiener 1977, 21; 1994, 26, 37-9; see also Byrd 2008, 83).
[56] Tsangadas 1980, 54; see also van Millingen 1899, 269-79; Guilland 1950; Janin 1964, 234; Müller-Wiener 1977, 60; 1994, 9-10).
[57] Mango 1993, 120-21; 2001, 25; see also Janin 1964, 225-28; Berger 1993, 468-69; Müller-Wiener 1994, 9.
[58] According to Müller-Wiener (1994, 9), a reference in the tenth century *Patria* indicates that the Eleutherian Harbor was reclaimed with fill from the construction of the *Forum Taurii* by Theodosius I, and the original harbor was to the east of the Theodosian Harbor. The confusion stems from the conflation of the two harbors by the French humanist Pierre Gilles/Petrus Gyllius, who authored an early study of Constantinople's ancient monuments in the sixteenth century (Byrd 2008, 201; see also Tsangadas 1980, 57; Guilland 1969, 111; Janin 1964, 225-28).
[59] Mango 2001, 25; see also Berger 1993, 468-69.
[60] Müller-Wiener 1994, 9.

and surrounded by a pair of breakwaters.[61] The size and boundaries of the harbor are still only partly understood, but it was certainly the largest commercial harbor of the city. C. Mango estimates the harbor basin as about 700 meters wide, although the Yenikapı excavations show it may well be larger; the Yenikapı excavation area, which is 900 meters long, has disclosed only the location of the western and northern ends of the harbor in some areas.[62] Sea walls were built around the southern shore of the city by the mid-fifth century and surrounded the interior of the harbor area as well; substantial remains of the sea walls of the Theodosian Harbor are visible today (**Figure 1.4**).[63] Remains of stone and concrete piers built for mooring ships and unloading cargo were discovered along the northern and western edges of the Yenikapı excavations, although little remains of the harbor's breakwaters, which we know primarily from later historical references, drawings, and maps dating from the fifteenth century and later.[64]

[61] Tsangadas 1980, 53-4, 56-8; see also Berger 1993, 470-72. Tsangadas states that the breakwaters were also fortified with walls, but this is not certain. The earliest detailed representations of the city, from copies of Cristoforo Buondelmonti's *Liber Insularum Archipelagi* (completed after 1418, and recopied many times over the course of the fifteenth century), show the breakwaters of the Theodosian Harbor without walls or only with a tower (also mentioned by Pierre Gilles) at the end of the breakwater (van Millingen 1899, 298; see also Tsangadas 1980, 57; Manners 1997, 73, 76, 78-84; Byrd 2008, 201). The moles around the Julian Harbor to the east were topped with walls, based on a description of the harbor by Corippus in the sixth century (Cameron 1976, 89; see also Magdalino 2000, 217).
[62] Mango 1993, 121; see also Gökçay 2007a, 166. Van Millingen (1899, 298) estimates the harbor's size as "786 yards from east to west and 218 yards from north to south." A clear eastern end of the harbor has not been discovered. Shipwrecks have been found up to the eastern end of the excavation area at the edge of Ataturk Boulevard (whose construction may have destroyed remnants of the eastern walls of the harbor, shown on a map by van Millingen) (1899, 268; see also Berger 1993, 467-68). These shipwrecks may have been located near the shoreline.
[63] Tsangadas 1980, 57; see also Croke 2005, 61; Mango 2001, 25-8. In the *Chronicon Paschale*, Theodosius II is recorded as ordering the construction of sea walls for the city in 439; however, they are not described in historical documents until a renovation around AD 700, and at least one seventh century source on the Avar siege seems to suggest that there were no walls on the side of the Golden Horn (Mango 2001, 24).
[64] Gökçay 2007a, 168-73; see also Berger 1993, 470-77.


Figure 1.4: Section of the Byzantine harbor walls along the edge of the Theodosian Harbor, preserved along on Küçük Langa Street, Yenikapı, Istanbul, December 2008 (Photo by the author).

For most of the city's history, the Golden Horn, the large natural anchorage along the north shore of the city, was the main hub of maritime activity and commerce. However, according to Magdalino, this activity was more evenly distributed between the northern and southern coasts of the city from the fifth to the thirteenth centuries due to the construction of the artificial Julian and Theodosian Harbors on the south coast.[65] Although the north coast was superior in terms of protection for ships, contrary winds

[65] Magdalino 2000, 211.

and currents in the Bosporus made the Golden Horn more difficult to enter from the south than a harbor on the south coast.[66]

Twenty state-owned *horrea*, or warehouses, are recorded in Constantinople in the *Notitia Urbis Constantinopolitanae*; these were situated on level ground near the harbors and held grain reserves, olive oil, and wine.[67] The *Notitia* lists several *horrea* by their function; for example, the *Horrea Alexandrina*, one of two state warehouses located between the Julian and Theodosian Harbors, likely stored grain from Egypt, while *horrea olearia* on the Golden Horn likely stored oil; others may have stored both oil and wine, as at Rome.[68] North Africa was likely a major source of olive oil until the Vandal conquest, after which North Syria seems to have become a major source of both olive oil and wine until the seventh century.[69] The *Notitia* also lists the city's bakeries, 20 of which were government-owned, in addition to 120 private bakeries, and four to five *macella*, or food markets, usually specializing in meat and fish.[70] As with the *horrea*, *macella* were often situated near harbors to facilitate the unloading of fish and livestock from vessels in the harbors.[71] In Rome, government bakeries were typically large-scale operations requiring significant manpower. Laws dating to the late Roman and early Byzantine period went to extraordinary lengths to keep bakers from abandoning their

[66] McCormick 2005, 86.
[67] Mango 2000, 193.
[68] Mango 2000, 193. Magdalino states that a larger number of storehouses were closer to the Golden Horn, and this region is described in the *Notitia* as housing the "essential buildings of the city"; the apparently lesser storage facilities near the southern harbors may indicate that the ports on the Marmara shore were intended for other goods in addition to basic food supplies, such as building materials required for the expansion of the city in the Late Roman period (Magdalino 2000, 211-12).
[69] Decker 2001, 70-1, 82-3; 2009, 245.
[70] Jones 1964, 2:701; see also Mango 2000, 193-4, 197-98.
[71] Jones 1964, 2:701; see also Mango 2000, 193-4, 197-98; Magdalino 2007a, 23.

professions, sentences to labor in the state bakeries were prescribed as punishments for various crimes such as indigency.[72] Bakeries connected to the *annona* were probably situated close to the *gradus* distribution points for *annona* bread.[73] Over 120,000 of the citizens of Rome were fed on the *annona* shipments in the late fourth century C.E., and when the practice was transferred to Constantinople, similarly large numbers were fed as well.[74] One law from the reign of Justinian I mentions an annual importation of 8,000,000 *artabae* of grain from Alexandria to Constantinople annually; according to one estimate, this is enough grain to feed 600,000 in a year, although some of this amount was certainly stockpiled in case of famine.[75] During the fourth and fifth centuries, surplus Egyptian grain was allocated primarily for Constantinople, while the *annona* at Rome continued, being supplied primarily by grain from North Africa.[76] Typically, grain ships traveling from Egypt to Constantinople were able to make two or three trips each sailing season.[77] North Africa and Sicily were also sources of *annona* grain for Constantinople, although in periods of shortage other regions would have been exploited as well.

[72] Jones 1964, 1:692, 699-701; see also Pharr 1952, 418; Rickman 1980, 205-6; Oikonomides 1995, 223-24. According to Jones, each of the public bakeries of Constantinople would have been large enough to feed at least 4,000 every day (Jones 1964, 2:701).
[73] Mango 2000, 190, 194; see also Rickman 1980, 208; Crow 2007, 256-57.
[74] Rickman 1980, 198. One of Justinian's edicts states the *annona* in Rome reached its height under Augustus, who fed 200,000, while in Constantinople under Constantine I, 80,000 were fed by the *annona* shipments (Jones 1964, 1:696).
[75] Mango 1985, 37; see also Durliat 1995, 21-2; McCormick 2005, 97. Mango (1985, 37) assumes that the great *artaba* of 4 1/2 *modii* (approximately 40.5 liters) is the unit of measurement here, in keeping with references in contemporary Egyptian papyri (the smaller *artaba* is approximately 3 *modii*). See Rickman (1980, xiii) for slightly different values for the *modius* and *artaba*.
[76] Rickman 1980, 198, 201.
[77] Grain ships on the Alexandria-Rome route could usually make only two trips a year at most (Casson 1995, 298-99).

Shippers involved in transporting grain and other staples to Rome and Constantinople were organized into a state-controlled guild of *navicularii,* property owners who were required to build ships of a certain size and transport grain to the capital at their own expense.[78] The ships of the *navicularii* were required to sail to the capital with an *annona* cargo once every two years by the shortest possible route to their destination.[79] Grain cargoes were to be sold at a fairly low set price, a measure which prohibited their sale at excessively high prices during periods of shortage.[80] These ships could be ordered to sea during the dangerous winter season (roughly October 15th to the end of March, although different dates are given in various ancient sources) if deemed necessary by the imperial administration, despite the fact that the grain fleet did not normally sail in this period; textual sources often describe the winter months as closed to shipping.[81] In

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[78] Pharr 1952, 391-99. A law by the emperor Claudius in the first century C.E. indicates that the minimum suitable capacity for a ship carrying state grain was 10,000 *modii* (68 tons), while port regulations from third century B.C.E. Thasos require grain ships to have at least 3,000 talents burden (80 tons); by the end of the second century C.E., grain ships of 50,000 *modii* (340 tons) were standard, while the largest grain ships' capacities on the Rome-Alexandria route in the early imperial period were between 1,200-1,300 tons (Rickman 1980, 123-24; see also Casson 1995, 171-73, 183-90, 369; Pomey and Tchernia 1978). A similar third-century law required river boats on the Tiber that worked supplying the city to have a minimum cargo capacity of 40 *cupae* or 'barrels' (Pharr 1952, 540; see also McCormick 2012, 75-6). The government also reserved the right to charter any ship with a cargo capacity of 2,000 *modii* or more (Jones 1964, 2:829). Most of the cargo ships found at Yenikapı are at least this size (i.e., 8-15 meters in length, with cargo capacities of under ten tons to perhaps 30 tons) as are the majority of ancient and early medieval shipwrecks known from the Mediterranean. Ships of this size would have been far more typical than the larger ships (see Casson 1995, 171-73, 183-90; Pryor 2008, 486; McCormick 2005, 95-6). YK 22, a very large sixth or seventh century shipwreck found at Yenikapı (YK 22) is probably in the size range of the larger grain ships of the period (Kocabaş 2012a, 109). Several shipwrecks from before the seventh century had cargo capacities of up to 200-300 tons (van Doorninck 1972, 139; 2002a, 899).

[79] This later changed to once every year to discourage trading in government grain (Jones 1964, 2:828-29).

[80] Rickman 1980, 202-3; see also Jones 1964, 2:828-29; McCormick 2005, 87.

[81] Rickman 1980, 202; see also Sirks 1991, 202-3; Davis 2009, 69-73. There is abundant evidence that sailing in the 'closed' season of the year occurred in the Mediterranean since at least the Classical period, and may have been routine for some types of vessels and for sailing on some routes (Yardeni 1994; Casson 1995, 270-73; Avramea 2002, 78; Davis 2001, 31-40; 2009, 65-76). McCormick (2005, 450-68) states the "sea closure was not an absolute rule" and collects numerous references from the seventh to late-tenth centuries of winter sailing. The feasibility of winter sailing depended a great deal on local environmental conditions, such as geography, weather conditions, and departure time (in McCormick's list

exchange, the *navicularii* were exempt from all other taxes and requisitions, particularly onerous land taxes and city council service; customs duties may have been waived as well.[82] This offered merchants and shippers other lucrative opportunities for profit and likely encouraged long-distance trade in a variety of commodities.[83] Unlike private merchants, *navicularii* were not legally responsible for legitimate losses of state goods at sea, and the provinces were also required to supply the *navicularii* with timber to build their ships.[84] In addition to the direct involvement of *navicularii* on the supply routes to Constantinople, the economic activity and maintenance of ports on these routes would have had significant indirect benefits, encouraging private merchants unaffiliated with the *annona* to use them as well.[85] In spite of the advantages offered to *navicularii*, some must have attempted to avoid these obligations, based on the number of laws for punishing those who did not fulfill their *annona* duties.[86]

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of documented early medieval voyages, there are far fewer recorded voyages in January and February than in the other months of the 'closed' season), as well as on the intended destination, route, itinerary, and other motives of the travelers. Tammuz (2005) and Davis (2009, 65-76) cite textual evidence for similar voyages from the Bronze Age to the Hellenistic period, and notes that certain deepwater routes, such as one between Alexandria to Rhodes, were also utilized in winter. Vegetius' military treatise from the fourth century C.E. contains and extensive passage on winter sailing; he specifies that winter sailing for military fleets is too risky, although some merchants sail in the winter months (Veg., *Mil*. IV.39; see also Tammuz 2005, 146; Davis 2009, 66-8). His advice is particularly relevant for ships traveling in fleets or convoys (including the Alexandrian grain fleet), which could be scattered by stormy weather; thus, naval expeditions in winter could have potentially disastrous results, particularly for galley fleets, since galleys were much less seaworthy than merchant ships (Pryor 2002, 43-7, 51-2; 2008, 484, 489; Davis 2009, 72-3). In general, it appears that there was a reduced volume of shipping in winter, and much of the shipping activity would be confined to smaller vessels engaging in short coastal voyages, but larger vessels and even fleets would have sometimes sailed in the winter as well.

[82] McCormick 2005, 89.

[83] Jones 1964, 2:828; McCormick 2005, 87-90. For a summary of archaeological evidence for private-trade goods such as fineware pottery, which may have been transported on *annona* ships, see McCormick 2005, 99-103.

[84] Pharr 1952, 393; see also McCormick 2005, 88.

[85] McCormick 2005, 90-2, 99-101.

[86] Pharr 1952, 391-99; see also Mor 2012, 48-55.

In the fourth century, the Theodosian and Julian Harbors were designed to accommodate the largest ships of the period.[87] During the sixth century, however, grain warehouses were constructed by the emperor Justinian on the island of Tenedos near the Dardenelles in order to make the transport of grain easier for large grain carriers. Because the currents and winds in the Sea of Marmara are generally from northeast to southwest, this final leg of the passage to Constantinople was difficult.[88] The option of unloading grain at Tenedos rather than Constantinople was likely preferable for many shippers, since it allowed *annona* ships to minimize their time in the Sea of Marmara and thus gain more time for additional voyages during the sailing season. Once their cargoes were discharged at Tenedos, smaller vessels could transport their cargoes to the capital.[89] This change may be reflected in the shipwreck remains from Yenikapı, many of which are much smaller than the vessels mentioned in connection with the *annona* trade from the early Imperial period. The remains of the largest ship from the Theodosian Harbor appear to date to the earlier period of the harbor's use, which roughly coincides with the construction of Tenedos as a major grain depot.[90]

The *annona* system began to break down during the period of crisis in the Byzantine Empire beginning in the early seventh century. In spite of the eventual Byzantine victory under the emperor Heraclius (610-641), the Persian-Byzantine war of 605-628 caused widespread devastation in the empire and may have greatly contributed to the relative

[87] Casson 1995, 171-73.
[88] Procop. *Aed*. V.i.8-10.
[89] Magdalino 2000, 215; see also McCormick 2005, 104.
[90] YK 22, the largest shipwreck from the Yenikapı site, probably dates to the sixth century based on radiocarbon-dated timber samples (Kocabaş 2012a, 109).

ease of the early Arab conquests beginning in the 630s.[91] Most of the Byzantine-Persian war was fought inside the boundaries of the empire, and must have strained the resources of the capital (armies on both sides would have lived off the land as much as possible) and caused the displacement of large numbers of people.[92] In the course of these wars, the wealthiest and most populous areas of the Byzantine Empire were lost. The provinces of Syria and Egypt were first overrun by the Persians, who held them for a period of ten years (616-626), then recaptured by the Byzantines, and finally overrun by the Arabs between 634 and 642.[93] The North African provinces, the other major source of *annona* grain, were gradually conquered by the Arabs over the course of the seventh century: Carthage was finally lost in 698.[94] The last recorded *annona* fleet was in 618 during the reign of the emperor Heraclius; although occasional grain shipments to the capital from Sicily and North Africa may have occurred after this date, these were likely at a small scale and insufficient for the needs of the capital.[95] In addition to losses by conquest and a long-lasting Arab naval threat, Constantinople was faced with major sieges in 626, when a combined force of Avars and Persians besieged the capital, and in 674-678 and 716-717 when Arab armies and naval forces attempted to take the city.[96] The Empire's borders had stabilized by the eighth century, and, despite further losses in

[91] Laiou and Morrisson 2007, 39; see also Haldon 1990, 42-53, 103-5.
[92] Teall 1959, 100. Teall (1959, 104) notes that, according to Theophanes, the emperor Artemius (Anastasius II, 713-715), faced with a siege of Constantinople by Arab forces, followed Byzantine military treatises by ordering all those who could not store three years' supply of grain in the city to flee.
[93] Angold 1985, 3; see also Haldon 1990, 42-50; Laiou 2002a, 13.
[94] Teall 1959, 91, 94; see also Laiou and Morrisson 2007, 43.
[95] Toynbee 1973, 212; see also McCormick 2005, 104, 111; Teall 1959, 97-8. Mango (2000, 198) notes that military *annona* distributions continued.
[96] Angold 1985, 3.

subsequent centuries (notably Sicily and Crete), remained largely the same from the late eighth to the early eleventh centuries (**Figure 1.5**).

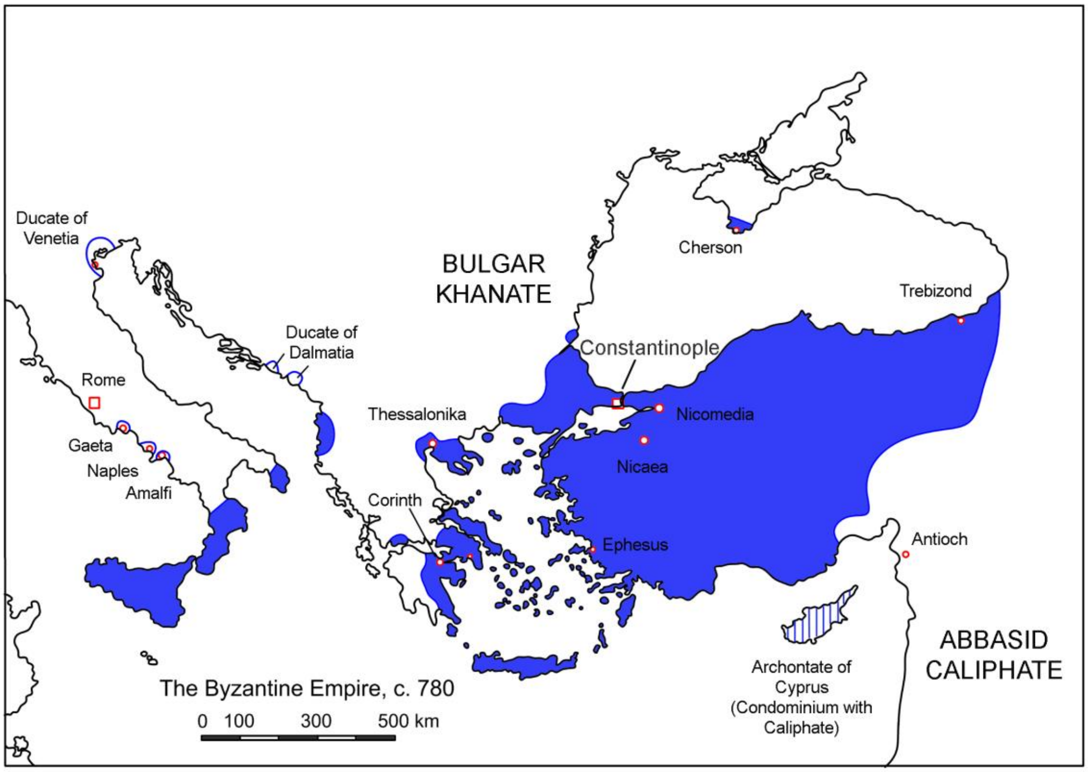

Figure 1.5: The Byzantine Empire, c. 780. Protectorates of the Empire are outlined in blue, while governance of Cyprus was shared between the Byzantine Empire and the Abbasid Caliphate. (After Treadgold 2002, 130).

The seventh century saw a major decrease in population in the capital caused by a combination of plague epidemics, which had begun striking the empire in the sixth century, the effects of war, and the end of the *annona* system. Although accurate population estimates for Constantinople in this period are not possible in the absence of substantial documentary evidence, during the seventh century the city may have had as few as 40,000-70,000 people; this population had decreased from a total of up to 500,000 in the mid-sixth century before the first outbreak of the bubonic plague in 542.[97] By all accounts this first epidemic was devastating; Procopius, who survived the infection, reports that victims died more quickly than they could be buried.[98] Subsequent recorded epidemics spread across the Mediterranean in 558-61, 571-74, 597-601, in the 660s, and, finally, a devastating outbreak that reached Constantinople in 747.[99] During periods of plague from the sixth through eighth centuries, unused cisterns in Constantinople were used to bury plague victims or as gardens, a sign of dramatically decreased population.[100] The long-term effects of these plague epidemics are debated, but they may have contributed to the breakdown of urban life and the Mediterranean economy, as large numbers died and others fled disease-ridden areas. The infection traveled especially quickly along sea routes and appears to have caused a particularly

[97] Horden 2005; Teall 1959, 92. No solid population figures for Constantinople during the Early and Middle Byzantine periods survive, but scholars tend to agree on the general trends. Estimates for Constantinople before the mid-sixth century Justinianic plague run from 250,000-600,000 (Jones 1964, 1: 698; Mango 1985, 54; 1993, 120; Durliat 1995, 21-2; Morrison and Sodini 2002, 174; Magdalino 2002, 529; Croke 2005, 67). Magdalino cites the 70,000 figure for the seventh century and believes Mango's figure of 40,000 is too low (Magdalino 2007, 18-9; see also Mango 1993, 120, 128-29). After the seventh century, the city's population slowly increased to 100,000-250,000 in the ninth and tenth centuries (Koder 2002, 110; see also Whittow 2008, 485), and continued to prosper in the eleventh and twelfth centuries. During the Fourth Crusade, Geoffrey of Villehardouin estimated the population of Constantinople at 400,000 (… "And they certainly should have praised Our Lord, since they had no more than 20,000 armed men among them, and they had conquered 400,000 men or more in the strongest city in all the world, a great city and the best fortified."), although this figure, as with most large figures in medieval sources, should probably not be taken literally (Smith 2008, 67; see also Koder 2002, 110; Magdalino 1995, 35; 2007, 61-5). It is clear from contemporary sources from the Middle Byzantine period that Constantinople was considered to be so large as to be in a class of its own; the twelfth century traveler Benjamin of Tudela considered Baghdad to be the only city of comparable size to Constantinople (Geanakoplos 1986, 278). In estimating the fresh vegetable requirements of Constantinople before 1204, Koder (1995, 50) assumes a population of at least 100,000 throughout the period.

[98] Procop. *Bell*., II.XXII-XXIII; see also Horden 2005, 139-42.

[99] Teall 1959, 101; see also Horden 2005, 138; Mango and Scott 1997, 585-86.

[100] Teall 1959, 103; see also Angold 1985, 3.

high mortality rate in maritime communities and urban populations.[101] Occasional bubonic plague outbreaks would have decreased the population, limiting manpower for agriculture and production as well as military service. Accounts of the period include frequent references to forced resettlement of depopulated areas, large-scale slave raiding by the Arabs, and ransoming of captives by the Byzantine state, indicating that "manpower had become a precious commodity."[102]Although the plague in this period was certainly a factor, the territorial losses of the empire to the Persians, Arabs, and other groups are likely more responsible for the economic contraction in this period, especially since the plague heavily affected the Caliphate as well.[103] Regardless of the cause, however, the end of the plague epidemics in the Mediterranean in the mid-eighth century coincides with the gradual recovery of the Byzantine Empire's economic and military fortunes and evidence for the gradual increase of maritime trade.[104]

The effects of this crisis period are highly visible in the archaeological record and in the textual evidence from this period. Coin finds on Byzantine sites drops drastically in the seventh century, especially finds of copper coins, which would have been used in small-scale daily transactions. [105] Copper as well as gold continued to circulate, but appears to have been minted primarily for the payment of government officials and the military; coinage does not again become common until the late eighth or ninth century, when the

[101] McCormick 2003, 16; 2005, 109. Whittow (1996, 66-8) argues that the long-term negative effects of the plague on Mediterranean population economic activity may have been exaggerated by modern scholars.
[102] Auzépy 2008, 260-61.
[103] Magdalino 2007a, 19, 54; see also Horden 2005, 138-39.
[104] Angold 1985, 6; see also Laiou and Morrisson 2007, 43-7; Mango 2005, 80.
[105] Morrisson 2002, 954-57.

economy had improved and most taxes were required to be paid in coin.[106] A similar impoverishment of material culture is seen in most categories of artifacts; imports such as fineware ceramics, which had been widespread in the Roman Empire, became rarer and were replaced by locally-made substitutes as long-distance trade declined.[107]

While much of Asia Minor appears to have prospered in the sixth century in spite of the increased threat of barbarian incursions, by the seventh century most cities in the region are abandoned or drastically reduced in size to the scale of small towns or fortresses; during this period the word *polis* (city) is replaced by *kastron* (fortress) in surviving documents.[108] Of the major cities and towns of the Byzantine Empire, only Constantinople, Thessalonica, and a much-reduced Ephesus were significant urban centers after the seventh century.[109] While the needs of the Empire's capital city continued to be met by the provinces, Byzantine society became predominantly rural.[110] In most cases, Byzantine cities occupied the same sites as those of classical antiquity. But the character of settlements changed, as a tenth century anonymous Persian source (the *Ḥudūd al-'Ālam,* 'The Regions of the World') relates:

> In the days of old cities were numerous in Rūm, but now they have become few. Most of the districts are prosperous and pleasant, and have (each) an extremely

[106] Hendy 1985, 640-45, 664; see also Whittow 1996, 105-6; Oikonomides 2002, 978-81, 995-1004; Laiou 2002e, 1146; 2002d, 708-9, 712-13.
[107] McCormick 2005, 98-103, 116-18; see also Morrisson 2002, 954.
[108] Foss 1977, 485-86; 2010, 116-24; see also Angold 1985, 4-5, 15; Whittow 2008, 470; Haldon 1999a; Teall 1977, 205.
[109] Foss 1977, 485-86; 2010, 117-23; see also Haldon 1990, 112-14; Angold 1985, 4-5; Bouras 2002, 501-9.
[110] Laiou 2002d, 700; see also Dagron 2002, 394-96.

> strong fortress, on account of the frequency of the raids which the fighters of the faith direct upon them. To each village appertains a castle where in time of flight [they may take shelter].[111]

Most Byzantine settlements of any size had changed from the classical *polis* to small fortified towns or castles that served as administrative or military centers and places of refuge.[112] Constantinople had an outsized influence on the empire as a whole even before the seventh century. However, after the first half of the seventh century, this feature of Byzantine society was even more pronounced; often the word *polis* was used to refer exclusively to Constantinople.[113]

The imperial government responded to its massive loss of revenues from Syria and Egypt by developing the thematic system, probably some time in the seventh century.[114] This system involved distributing land grants to soldiers' families in lieu of one-half of the pay they had previously received.[115] Supplies required for provisioning soldiers could be levied from these lands or the region's population, and their arms and equipment would be sold to them at fixed prices from government factories run by private contractors.[116] This system shifted much of the burden of equipping and supplying soldiers from the central government to the local population, gave the state a

[111] Minorsky 1937, vii, 157; see also Haldon 1990, 112-13; 1999, 14-5.
[112] Haldon 1990, 113-15; see also Auzépy 2008, 263-65.
[113] Haldon 1999a, 17; see also Bouras 2002, 501-2.
[114] Haldon 1999b, 76-85; 2008, 555-57; see also Louth 2008, 239-40; Auzépy 2008, 266-69.
[115] Treadgold 1997, 315-17.
[116] Haldon 2008, 555-56; see also Treadgold 1997, 318; Auzépy 2008, 268-69.

mechanism for settling and defending threatened areas, and decreased the amount of coinage necessary for paying the army.[117]

The status of Constantinople's population and economy from the seventh to ninth centuries is known mainly through indirect documentary references. The *Chronicle of Theophanes* records that in the 765/766, during a period of drought, Constantine V (741-775) ordered repairs to the Aqueduct of Valens, which had been cut by the Avars in the siege of 626. The emperor "collected artisans from different places and brought from Asia and Pontos 1,000 masons and 200 plasterers, from Hellas and the islands 200 clay-workers, and from Thrace itself 5,000 laborers and 200 brickmakers… When work had thus been completed, water flowed into the City."[118] This passage has been interpreted by some scholars as significant evidence for economic and social conditions in eighth century Constantinople. The fact that Constantine V needed to import artisans from other regions of the empire has been plausibly cited as evidence of a shortage of manpower and an example of the degraded condition of urban life in Constantinople and in towns and cities in the empire in general.[119] Theophanes also records Constantine V's forced relocation in 754 of inhabitants of Greece and the Aegean islands to the capital, in order to increase its population after the plague epidemic of 747.[120] Similarly, an edict of Leo III's (717-741) from 732 concerns a new tax to pay workmen to repair the city walls after a major earthquake; since the city's guilds would normally do such work, this edict

[117] Haldon 2008, 556; see also Treadgold 1997, 317-18.
[118] Mango and Scott 1997, 608; see also Mango 1995, 17; Magdalino 2002, 532; Crow and Bayliss 2004, 45.
[119] Laiou 2002b, 49-51; see also Magdalino 2007b, 3, 5-6, 11-2.
[120] Mango and Scott 1997, 593-94; see also Teall 1959, 101-3; Toynbee 1973, 216.

implies that sufficient manpower was not available in the city.[121] These references suggest a much-reduced population for Constantinople in the seventh and eighth centuries in comparison to earlier periods. However, the fact that Constantine V considered such repairs necessary can also be interpreted as evidence for an increasing population in Constantinople in the eighth century after a long period of demographic decline, and may have been one of the first signs of the city's gradual recovery.[122] Toynbee notes that Constantinople's population was also increased by influxes of refugees during periods of warfare and unrest.[123]

The drop in Constantinople's population in the seventh and eighth centuries was beneficial in some respects in that local resources could supply more of the inhabitants' needs.[124] J. Koder surmises that the city's needs for fresh produce could be supplied by the immediate hinterland around the city and on the Asian shore of the Bosporus.[125] Crops and orchards grew in the area outside of the walls, and were even harvested by the inhabitants during sieges.[126] As in later periods, much of the area between the walls of

[121] Teall 1959, 102.
[122] Angold 1985, 6; Mango 2005, 80.
[123] Toynbee 1973, 214; Laiou and Morrisson 2007, 44-5.
[124] Teall 1959, 93. Toynbee (1973, 215-19) cites a military official in charge of Constantinople's defenses in 747 who complained that the city's population was too small, and notes the advantages and disadvantages of a smaller population in the capital from a military standpoint; while a smaller population was easier to feed and supply, less manpower also adversely affected the manning and maintenance of the city's defenses, which were built for a city on the scale of Rome at its height and were difficult for a smaller population to maintain.
[125] Koder 1995, 53-4; 2002, 112-13. The *Geoponika*, a tenth century agricultural manual consisting of excerpts from earlier sources, includes a passage on the wide variety of crops, vegetables, and herbs to be planted each month "in the latitude of Constantinople" (Dalby 2011, 9, 246-47; see also Koder 1995, 50-1).
[126] Howard-Johnston 1995, 138; see also Koder 1995, 53-4. According to Pseudo-Dionysius of Tel-Mahre, when faced with a Bulgar invasion in 540, imperial authorities cleared "Tall and strong trees, cedars,

Constantine and Theodosius was not occupied by buildings during this period, and was instead used to for crops, orchards, and pasture.[127] With a drop in population, more land for agriculture or pasture, in addition to abundant building material from ruined buildings, were available to the city's inhabitants.

The position of the city on the Bosporus, a major migration route for various species of fish between the Black Sea and the Mediterranean, was certainly exploited as a major source of protein.[128] Contemporary sources seem to indicate that fresh meat and fresh fish were eaten fairly infrequently by common people, particularly due to the expense of fuel for cooking in cities, but salted meat and particularly salted fish are frequently mentioned.[129] In this period, the imperial government's role in the grain trade had been reduced and had changed in character, but it was still heavily involved in the commerce and supply of the capital. Procurement of grain focused on supplies far closer than those from Egypt after the 640s: grain was imported primarily from the neighboring regions of Thrace, Paphlagonia, the Pontus, and Bithynia.[130] This trade was in the hands of private merchants, but in a crisis such as a famine or siege civic leaders (who also frequently engaged in merchant activities themselves at a significant scale) could organize purchase and supply of necessities.[131] Maritime trade, although decreased from pre-seventh

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cypresses, nut and fig trees, as well as vineyards and gardens" up to 100 cubits around the city walls (Witakowski 1996, 83).

[127] Koder 1995, 51, 53; Mango and Scott 1997, 586. Teall (1959, 104) believes that Constantinople in this period was still in the hundreds of thousands, and too large to be self-sufficient on local resources.

[128] Browning 1993, 100-1.

[129] Koder 2007, 60, 63-5; see also Freshfield 1938a, 38-41, 46-7.

[130] Teall 1971, 35-59; see also Haldon 1990, 11; Hendy 1985, 555-57.

[131] Teall 1959, 104-5, 114-15, 121-22; 1977, 203-4; see also Magdalino 1995, 37-41; Laiou 2002d, 705-8.

century levels, remained significant. References to shippers in the *Rhodian Sea Law* and saints' lives seem to describe relatively small-scale merchant ventures, with relatively little state regulation or interference. For example, the profit shares of the captain and crew are determined by their positions on board, and the shipowner himself (*naukleros*) often served the roles of a merchant and the ship's captain.[132] Based on Roman precendents, trade partnerships between captains and private investors similar to the later *commenda* contracts of the Middle Ages appear to have been common in the Byzantine Empire.[133] The church owned ships and was heavily involved in transporting and selling the products of church lands both before and after the seventh century; taxes may have been paid in kind with these products as well.[134] Theophanes records that Nicephorus I (802-810) forced reluctant ship owners in the city to accept a maritime loan of 12 pounds of gold from the state, probably as a way to stimulate commercial activity and gain revenue and control of commerce for the state.[135] An annual fair at the port town of Ephesus in the late eighth century yielded 100 pounds of gold in tax revenue, indicative of the continuation of significant levels of commerce.[136] Commerce was taxed and regulated by *kommerkiarioi*, imperial agents with several functions. Many were customs agents taxing imports into the empire; some initially bought silk imported from the East, but *kommerkiarioi* later dealt in other goods, served as quartermasters for the army, and

[132] "A master's pay two shares; a steersman's one share and a half; a master's mate's one share and a half; a boatswain's one share and a half; a sailor's one share; a cook's (?) half a share" (Ashburner 1976, 57-9; see also van Doorninck 1972, 139; Laiou 2002d, 707-8).
[133] Lopez 1959, 81-2; see also Freshfield 1938b, 103-7; Ashburner 1976, 68; Laiou 2002d, 711.
[134] Monks 1953; see also van Doorninck 2002a, 901.
[135] Treadgold 1988, 165-6; see also Mango and Scott 1997, 668; Laiou 2002d, 711.
[136] Laiou 2002d, 709.

seem to have been involved in private entrepreneurial activities as well.[137] By the mid-ninth century, the *kommerkion* is a sales or import tax, which was levied on, among other things, the cargoes of ships sailing into either end of the Sea of Marmara.[138]

Although large parts of Constantinople's supply infrastructure from the fourth and fifth centuries were still in operation in the seventh century and later, activity around Constantinople's four main harbors had changed significantly. On the Golden Horn, the Prosphorion Harbor may have been abandoned,[139] while the Neorion Harbor was dredged in 698 to accommodate the navy, an event Theophanes blames for an outbreak of plague in the city.[140] The Julian or Sophian Harbor on the Marmara shore appears to have been the main commercial harbor for the city based on textual sources.[141] This shift may have occurred as early as the sixth century; this area was apparently renovated by Justin II (565-578) after a large fire in Justinian's reign, and continued to be an

[137] Oikonomides 2002, 984-85; see also Kazhdan 1991, 2:1141; Dunn 1993; Laiou 2002d, 706.
[138] Oikonomides 2002, 986; Kazhdan 1991, 2:1141-142.
[139] Magdalino (2007a, 20) states that the Prosphorion Harbor had fallen out of use, while Mango (2000, 199, 204) believes that the Prosphorion Harbor may have continued to be in use into the tenth century, based on the location of some of the major meat markets at the Strategion near the Golden Horn. Magdalino notes that the meat markets in the *Book of the Eparch* are divided evenly between the Strategion and the Forum Taurii between the Theodosian and Julian Harbors, with the south coast taking more of the traffic in livestock in this period (Magdalino 2000 214-15).
[140] Magdalino 2007a, 20; see also Scott and Mango 1997, 517. Magdalino (2000, 217-19) notes that the dredging of the Neorion Harbor at this date suggests that it had been out of use for some time, and that Theophanes' implied association of the harbor with plague may be a recollection of the Justinian plague of 542. Medical knowledge of the time associated disease with "corrupt air" produced by rotting organic material and moisture; dredging a harbor may have been seen as releasing such noxious vapors (The Yenikapı excavations show that the harbor was full of garbage; even dead horses and a dead camel were dumped in the harbor. See Onar et al. 2010, 224-31). This may have been compounded by the lack of strong currents to flush out the Golden Horn, in contrast to the harbors on the Marmara shore. According to one account, during the plague of 542 large numbers of bodies were disposed of in the Golden Horn area by dumping them in the harbor and along the shoreline (Witakowski 1996, 88-91). According to Magdalino, this association of the Golden Horn side of the city with the plague may, have shifted the heaviest commercial and residential concentration from the northern to the southern side of the city from the sixth through the twelfth centuries (Magdalino 2000, 217-19).
[141] Magdalino 2000, 212-13; 2007a, 20, 23.

important commercial harbor into the twelfth century.[142] The Theodosian Harbor was silting up—the last explicit textual reference to its use dates to 673—but the Yenikapı excavations as well as indirect documentary references to the use of the port area show that a significant harbor basin survived on the eastern end until at least the late tenth century.[143]

Beginning in the ninth century and continuing into the tenth, the political and economic fortunes of the Byzantine Empire slowly recovered. The borders were first consolidated in the later eighth century and then expanded as some of the territory conquered by the Arabs and Slavs in eastern Anatolia and the Balkans were retaken.[144] The empire's economic fortunes improved as well, as shown by increased coin finds in the ninth and tenth centuries, more numerous references to merchant activities, and signs of a slow increase in Constantinople's population.[145]

Several passages in late ninth- and early tenth-century texts suggest the continued importance of the Theodosian Harbor. A state-owned grain warehouse known as the *Lamia* (probably the fifth-century *Horrea Alexandrina* or the *Horreum Theodosianum*) was still used for its original purpose in the area of the Theodosian Harbor; a large

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[142] Magdalino 2000, 212; 2007a, 20, 23, 104; Cameron 1968, 14-5.
[143] Magdalino 2007, 20; see also Pulak 2007a, 202-3; Perinçek 2010, 210-1, 215-16; Tsangadas 1980, 56-8. Theophanes mentions the assembly of a fleet in 673 in the harbor of Caesarius, another name for the Theodosian Harbor, to counter an expected Arab naval attack (Mango and Scott 1997, 493). Mango states that the Theodosian Harbor area was used for a military harbor in the thirteenth century, but so far no clear archaeological evidence for this has been found (Mango 2001, 25).
[144] Shepard 2008b; see also Laiou 2002a, 16-7; 2002d, 714-15.
[145] Supra n. 104.

number of the city's bakeries were in the same area, probably because of the necessity to import grain and charcoal by sea.[146] The *Book of the Eparch*, dating to 912, indicates that pigs and Easter lambs were sold at the *Forum Taurii* (Forum of Theodosius) near the Theodosian Harbor.[147] Most of the city's livestock had been shipped in by sea since the fourth century, a practice that continued into the Middle Byzantine period, particularly from the ports of Nicomedia (modern Izmit) and Pylae (modern Yalova).[148] Unlike the neighboring Julian or Sophian Harbor, there is no indication either from the Yenikapı excavations or documentary records that the Theodosian harbor was ever dredged.[149] This is probably due to the shrinkage of the city's population—the massive harbor facilities of the Late Roman period were no longer needed—as well as the adoption of more shallow-draft vessels for supplying the city following the establishment of the Tenedos granaries in the sixth century and the end of the *annona* in the seventh.[150] The earliest maps of Constantinople by the Florentine traveler Cristoforo Buondelmonti (dating to c. 1420 and later) show the Theodosian Harbor area as a river delta flanked on one side by a breakwater.[151] In the mid-sixteenth century, the French humanist scholar Pierre Gilles (Petrus Gyllius) described the site in his book *The Topography of Constantinople and Its Antiquities* as a somewhat marshy area with some

[146] Magdalino 2000, 213; 2007a, 23-6; see also Haldon 1986.
[147] Magdalino 2007a, 11, 26-7.
[148] Magdalino 2007a, 26; see also Hendy 1985, 55, 558-59, 561-64; Kazhdan 1991, 2:1483; 3:1760. In a letter to the emperor Basil II in 996, Leo of Synada complains of his treatment in the town of Pylae (modern Yalova on the Sea of Marmara) on the route to the capital, that "dumb animals take precedence over us in express transport to the capital" (Vinson 1985, 87-9, 137).
[149] Magdalino 2000, 215; see also Müller-Wiener 2004, 26-7. This is in contrast to the Julian Harbor, which was dredged in 509, and the Kontoskalion Harbor, which was dredged in the thirteenth century (van Millingen 1899, 291, 294).
[150] Magdalino 2000, 215; see also Mango 1985, 53.
[151] Berger 1993, 470-72; see also Manners 1997, 73, 76, Fig. 2.

remaining harbor works visible; in his time the Theodosian Harbor area, or *Vlanga Bostanı*, was the site of extensive vegetable gardens, a use for the area that continued until recently.[152]

During the Yenikapı excavations, a number of fairly small, shallow-draft vessels dating to the tenth century were discovered concentrated in the eastern end of the harbor, suggesting that this was the last section of the harbor to be used at a significant scale.[153] Most of the 36 shipwrecks found in the excavations sank after the seventh century, with the largest group dating from the ninth to the tenth- or possibly the early eleventh-century. Pilings from the Theodosian Harbor dated by dendrochronology indicate that docks were gradually extended across the harbor basin until the fifteenth century.[154] The evidence for docks discovered at Yenikapı matches Middle Byzantine period descriptions of the city. The Byzantine chronicler Michael Attaleiates, as well as the Arab geographer Mas'udi, describe the city's waterfront in the tenth and eleventh centuries as being covered by *skalai*, or quays, where small ships could unload cargoes shipped from small ports and landing stages elsewhere in the region.[155] *Skalai* were usually privately owned, belonging to aristocratic houses, monasteries and pious foundations, and foreign traders, who would have charged rent or duties for their use by

[152] Byrd 2008, xxi, 201; Berger 1993; Tsangadas 1980, 56. Gilles mentions a pier at the site visible in the sixteenth century which was 600 paces long (Byrd 2008, 201).
[153] Pulak 2007a, 202-3.
[154] Kuniholm et al. 2007, 381-83; see also Byrd 2008, 201; Berger 1993. Pilings and retaining walls were used in land reclamation on the Marmara coastline of the city, according to Zosimus and other writers from the fourth and fifth centuries (Mango 1990, 17-8; 2001, 17-9; see also Magdalino 2000, 215).
[155] Lunde and Stone 1989, 322; see also Magdalino 1995, 38-44; 2000a, 215; 2007, 55, 101-2. Based on twelfth-century land grants to Italian merchants, a *skala* consisted not only of a quayside built of an earth embankment fronted with a wall of pilings, but also a fenced area built over with houses, workshops, and booths of moneychangers (Magdalino 2000, 224).

others, in addition to utilizing them to sell their own products in the city.[156] Magdalino suggests that the prominence of these docks in contemporary descriptions indicates a shift in the supply infrastructure of the city from the large, state-run *annona* fleets, which required an extensive harbor infrastructure to accommodate its large grain carriers, to a more decentralized network run by private entities, which used smaller, shallow-draft vessels.[157] Documentary references to voyages in this period confirm the frequent use of anchorages without extensive port structures and that beaching ships was a common practice; large ships like the earlier *annona* vessels could not be used in this way.[158] These small ships would have been used to carry grain and other goods loaded in ports much closer to the capital than those from which the *annona* ships sailed, usually connected to aristocratic estates or monasteries which also owned *skalai* and other properties in the capital. Besides the evidence of contemporaneous shipwrecks, which will be discussed in the later chapters, documents recording the sizes of vessels owned by monasteries have survived in some instances. These ships were usually of small size, and were used not only for shipping and selling surplus products from monastic lands, but also for fishing and the sale of retail goods.[159]

Although the grain trade with Constantinople remained largely in private hands, government warehouses kept grain in case of famine, and the imperial government

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[156] Dagron 2002, 429.
[157] Magdalino 1995, 41-3; 2000, 215; 2007a, 101.
[158] McCormick 2005, 418-30.
[159] Harvey 1989, 238-41; see also Dagron 2002, 424, 426-28; Teall 1959, 126.

sometimes set price limits on grain during periods of scarcity.[160] Contemporary accounts of travel through the Sea of Marmara region describe numerous estates and small ports in the region engaged in shipping basic commodities to the capital.[161] This trade was shared between larger estates and small landowners and peasants; Michael Attaleiates identifies the port of Raidestos on the Sea of Marmara as one of the markets and collection points for the grain surplus sold by these producers for consumption in the capital.[162]

Governance and political power continued to be centralized in the state in the Middle Byzantine period, a centralization that included control of economic activity. The Byzantine state has been characterized as a "restrained" economy, or "an economy that functioned on the basis of the freedom of transactions but in which the state intervened to prevent the excessive accumulation of wealth, the suppression of the weakest, and the exploitation of the citizens/consumers."[163] The early tenth-century *Book of the Eparch* provides a vivid example of this economic philosophy as well as the most detailed surviving account of the commercial activity and provisioning of Constantinople.[164] The city's eparch was one of the top officials in the imperial court; he was responsible for the day-to-day running of the city and the monitoring of commercial transactions, performed by city officials and by regulation of state-organized trade guilds. Trade guilds were

[160] Laiou 2002d, 720; see also Monks 1953; Sirks 1991, 132-33; van Doorninck 2002a, 901. This change was well underway by the sixth century, according to van Doorninck (1972, 139).
[161] Teall 1959, 123-28; see also Magdalino 1995, 37-47; 2002, 531-32; Minorsky 1937, 156.
[162] Oikonomides 1995, 229; see also Magdalino 1995, 43; Kaldellis and Krallis 2012, 367-73; Harvey 1989, 236-37.
[163] Oikonomides 2002, 973.
[164] Freshfield 1938a, xi-xiii; see also Laiou and Morrisson 2007, 44, 57-8.

required to accept sometimes strict regulation by the imperial government in exchange for monopolies on their trades in the city.[165] The *Book of the Eparch* was written for the *symponos*, one of the eparch's officials, who was in charge of the city's markets, controlling weights and measures and instituting price and quality controls for various types of goods.[166] Besides guaranteeing certain rights of tradesmen, many of the regulations specify neighborhoods where specific trades are to be practiced in the city so that they could be more easily monitored by imperial officials; particular care was taken to prohibit hoarding, forgery, and the sale of forbidden products to unauthorized individuals or foreigners.[167] The regulated guilds include those working with precious materials, such as silk production, as well as jewelers and spice and textile merchants.[168] Statutes also covered bankers and moneylenders, goldsmiths, and notaries, whose numbers were strictly limited.[169] Silk cloth production was particularly important, and every stage of its manufacture was strictly regulated: as a lightweight, high-demand luxury product, it was frequently used for payments to government officials and soldiers as well as for diplomatic gifts to foreign powers and even for the ransoming of captives.[170]

165 Oikonomides 1995, 223-25.
166 Oikonomides 1995, 225; 2002, 975.
167 Toynbee 1973, 203-4.
168 Freshfield 1938a, 16-9.
169 Freshfield 1938a, 3-18, 21-7. Angold (1985, 24-33) notes that the number of notaries and their assistants are strictly limited in the *Book of the Eparch* (only 24 are allowed, each with a single clerk as an assistant), and their numbers are quite low in comparison to the hundreds of notaries employed in Italian cities in later periods.
170 Freshfield 1938a, 16-27; see also Laiou 2002cm 692-94; 2002d, 699, 715-19; Lopez 1945; Muthesius 1993; 2002; Maniatis 1999; Oikonomides 1986; 2001; 2002, 1011, 1014; Jacoby 2000a, 40-2; 2004; 2008.

Laws governing more mundane professions were also included in the *Book of the Eparch*, including grocers, perfume-makers, linen merchants, and chandlers, who were only allowed to sell certain items, and butchers, bakers, and fishermen, who played a vital role in provisioning the city. The importation of livestock was strictly regulated. Prices and profit margins for meat, fish, and bread were fixed by the eparch's officials, who also ensured the quality of goods and that all livestock were sold.[171] As with most of the other professions in the *Book of the Eparch*, bakers, fishmongers, and butchers were required to practice their trades in specific areas. Pork butchers were to buy, butcher, and sell pigs at the Forum Taurii; sheep were sold up to the first day of Lent in the Strategion, Easter lambs in the Forum Taurii, and cattle in the Amastrion market.[172] Fishmongers were required to buy fish from fishermen at the city's waterfront and were forbidden to go outside the city to buy fish; they were also required to sell the fish in a specific building, probably an old *macellum*.[173] They were also forbidden to sell salted fish to foreigners unless there was a surplus, in order to ensure the city's food supply in times of scarcity.[174]

The regulations in the *Book of the Eparch* were designed to protect the state's interest in luxury commodities such as silk and precious metals, to prevent counterfeiting of coinage, to protect consumers from fraud or excessively high prices for important commodities, to protect guilds from outside or unregulated competition, and to ensure

[171] Freshfield 1938a, 38-42, 44-6.
[172] Freshfield 1938a, 39-40.
[173] Freshfield 1938a, 40-1; see also Maniatis 2000, 18-24.
[174] Freshfield 1938a, 41.

the supply of food and other necessities for the city.[175] They were also designed to regulate foreign trade and the activities of foreigners within the empire. Most foreign merchants were allowed to stay in *mitata,* or hostels designated for foreign traders, in the city or the surrounding region for set periods in order to sell their goods. After the permitted period had expired, they were required to leave after an official government inspection of their goods to ensure that no forbidden items were being exported.[176] The Bulgars are specified as 'aliens' arriving at the city to sell linen and honey, and were dealt with through the linen merchants' guild.[177] "Syrian merchants" are mentioned as trading in luxury silks and other textiles from Muslim-controlled lands. Those importing silks were allowed to stay in a suburb of the city for three months at a time in order to sell their wares under the supervision of the eparch in a *mitaton*; dealers who came to buy the imported silks were required to share the purchases with "Syrian merchants who have dwelt in the capital for a continuous period of ten years."[178] It in unclear whether these were Muslim or Christian Syrian merchants, but it is likely that they were Muslim; a mosque in Constantinople is first attested in the twelfth century, but it is clear from Arab sources that merchants from the Caliphate were active in the city from at least the tenth century.[179] Syrian merchants also sometimes traded in spices and perfumes, which

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[175] Oikonomides 1995, 225; see also Toynbee 1973, 202-6; Laiou 2002d, 724-25.
[176] Freshfield 1938a, 19-20; see also Oikonomides 1995, 224.
[177] Freshfield 1938a, 28-9.
[178] Freshfield 1938a, 19-20; see also Oikonomides 1995, 231; Kazhdan 1991, 2:1385; Constable 2003, 147-150.
[179] Reinert 1998, 130-5. An Arab *mitaton* dating to at least the tenth century (and perhaps as early as the late seventh century) may have been located near the Venetian and Amalfitan *mitata* on the Golden Horn, according to Magdalino, who cites the longstanding commercial connections (particularly involving the slave trade) between these Italian cities and Arab North Africa. The Golden Horn area was also likely "the place for foreigners to trade" (Magdalino 2000, 220-22; 2002, 532). El Cheikh dates the mosque's construction to the early eighth century, after the 717 siege of the city, and shows from contemporary Arab

would be sold to the perfumers; the perfumers and spice merchants also purchased from traders from Trebizond and the "land of the Chaldees" who came to Constantinople via the Black Sea coast of Asia Minor.[180] Foreign merchants were frequently interested in luxury goods produced in the capital such as Byzantine silk textiles and metalwork, which were highly regarded outside of the Byzantine Empire.[181]

These interactions seem to be typical of Byzantine relations with foreign groups. Warfare with the Arabs was frequent, but it did not preclude more peaceful or mundane contacts.[182] Arabs and Byzantines came into contact not only through diplomatic envoys and from the ransom or exchange of captives, but also through the activities of merchants, who as lower-status individuals are often less visible in the documentary record.[183] The Serçe Limanı shipwreck provides clear archaeological evidence for one case of extensive commercial contacts between Fatimid Syria and Constantinople (see Chapter VII).[184] The slave trade in the Mediterranean was driven as much or more by economic considerations and circumstances as by ethnic or political divisions; contemporary sources (frequently clerics complaining about the sale of Christians to infidel Muslims) indicate that Arabs, Byzantines, and Italians all engaged in slave-raiding and the slave trade, with communities such as Naples, Amalfi, and Venice

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sources that some were very familiar with Constantinople's topography and major features (2004, 64, 139-64).

180 Freshfield 1938a, 30-1.

181 Laiou and Morrisson 2007, 84, 89, 138-39; see also Jacoby 2000a; El Cheikh 2004, 54-60; Laiou 2002d, 725, 749.

182 El Cheikh 2004, 2.

183 Reinert 1998, 125-40.

184 Bass et al. 2004; see also Bass et al. 2009; Bass and van Doorninck 1978; van Doorninck 2002b; 2012; and discussion of evidence of the ship's Syrian and Byzantine connections in Chapter VII.

forming close commercial links with Muslim North Africa.[185] Such familiarity was useful for reasons of strategy as well as mutual financial gain. The tenth-century Byzantine military treatise *On Skirmishing*, probably written by an officer in the emperor Nicephorus Phocas' army (963-969), encourages the use of merchants traveling to Muslim-held territories as spies.[186] This advice indicates that peaceful as well as warlike interactions between Byzantine and Muslims occurred on a significant scale. Christian pilgrims traveled to Jerusalem and other holy sites in Muslim-controlled areas throughout the period, usually by sea.[187] Other examples include the use of Byzantine engineers and skilled craftsmen, particularly for prestige projects such as the construction and decorations of mosques, and the transmission of philosophical and scientific knowledge between the courts of the Byzantine Empire and the Arab Caliphate.[188]

The presence of other foreign groups in Constantinople is mentioned in documentary sources of the period as well. The Rus, named after a coastal region of Sweden, were Scandinavian traders and mercenaries who settled in the territory of modern-day Russia

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[185] McCormick 2005, 618-38.
[186] Dennis 2008, 139, 163.
[187] McCormick 2005, 209-10, 590.
[188] Pryor 2000, 148-49. See also Koutrakou 1995 on the use of Byzantine merchants, pilgrims, and diplomats as spies. Several Arab commentators show that they were well aware of this role: the tenth-century geographer Ibn Hawqal complains that Byzantine merchants arrive in ships and penetrate into the interior of Muslim lands, collecting information with the assistance of greedy Muslims interested in profitable trade with the Byzantine Empire (Vasiliev and Canard 1950, 416; see also El Cheikh 2004, 151; Laiou 2002d, 723). El Cheikh (2004, 54-60, 103-11, 151) notes references in Arab sources to the high quality work of Byzantine craftsmen and their work on prestige projects in the Caliphate such as mosque construction (see also McCormick 2005, 591), as well as their transmission of ancient Greek texts to the Arab world. See Magdalino (1998) for intellectual discourse through embassies between the Byzantine Empire and Abbasid caliphate in the ninth century.

and eventually integrated into the local Slavic ruling class.[189] The Rus initially attempted to sack Constantinople several times in the ninth and tenth centuries, but peace negotiations after conflicts between the Rus and the Byzantine Empire included trade agreements with specific conditions for the accommodation of Rus merchants.[190] The Rus brought furs, wax, and slaves to exchange for manufactured and luxury goods in Constantinople; their *mitaton* was near the monastery of St. Mamas in Istanbul's modern neighborhood of Beşiktaş, on the northern shore of the Golden Horn.[191] Rus traders sailed on *monoxyla* (essentially dugout canoes) down the rivers of Russia to the Black Sea, where they were fitted with sails and rigging for the journey to Constantinople, a journey described in detail in the mid-tenth century diplomatic treatise *De administrando imperio* of Constantine Porphyrogenitus (913-959).[192] By the tenth century, Rus mercenaries served on Byzantine military expeditions; a contingent is mentioned in *De Ceremoniis* in a list of troops and naval forces assembled for the failed naval expedition to Crete in 911, and in the late tenth century Basil II (963-1025) won the decisive battle of an extended civil war with their help.[193] Rus mercenaries eventually became the basis for the Varangian Guard, an elite regimental bodyguard of the emperor.[194] A similar pattern seems to have been followed in relations between the Byzantine and Bulgar Empires. Their relations were frequently hostile, yet the Bulgars were heavily influenced by Byzantine culture. They traded extensively with the Byzantine Empire from at least

[189] Blöndal 1978, 1-4.
[190] Geanokoplos 1986, 284.
[191] Blöndal 1978, 12-3; see also Geanakoplos 1986, 284.
[192] Moravcsik and Jenkins 2008, 57-63; see also Blöndal 1978, 1-14.
[193] Sewter 1966, 34-5; see also Haldon 1999, 125; Blöndal 1978, 14, 32-45.
[194] Pryor and Jeffreys 2006, 548; see also Blöndal 1978, 20-1.

the late seventh century, and converted to Christianity, establishing a Bulgarian patriarchate that was officially recognized by the Byzantine emperor Romanus Lecapenus (920-944) in 927.[195]

Constantinople’s harbors along the Golden Horn again became a major locus of commercial activity by the eleventh century, in large part because of the foreign trade enclaves in the area.[196] Land grants were given to foreign traders to establish *mitata* in this area, across the Golden Horn in Pera, and in Constantinople’s suburbs.[197] These groups included Arabs, Jews (whose community was located across the Golden Horn in Pera by the mid-eleventh century, if not earlier), and Germans and French, whose presence in the city by the late eleventh century may have been related to the First Crusade.[198] The most important of these groups, however, came from Italian city-states.

The Venetians, former subjects of the Byzantine emperor, initially won a favored status by providing warships and crews for the imperial navy in various conflicts, but their activities involved trade in the Byzantine Empire at an early date as well.[199] By the ninth

[195] Laiou 2002a, 17-8; 2002d, 704; see also Freshfield 1938a, 28-9; Runciman 1966, 277-80; Treadgold 1997, 479.
[196] Magdalino 2000, 220-21; 2007, 88, 93. The equivalent for Byzantine and other foreign traders in Arab cities such as Cairo was the *funduq* or hostel (Jacoby 2000b, 34-5). For the history of hostels for foreign traders and other travelers in the Mediterranean into the early medieval period, see Constable 2003, 1-106.
[197] Land along the Golden Horn may have been available for land grants in this area in the tenth century since it was not as valuable as land along the southern shore, which was more sheltered from northern winds, and because there were few powerful interests with property in the area who would be offended by an imperial confiscation. The association of Italian rowers and sailors with the military Neorion harbor may have also played a role, as well as a desire to sequester and concentrate foreigners in more peripheral areas in and outside of the city (Magdalino 2000, 215-16, 220-21).
[198] Magdalino 2000, 220-21; see also Constable 2003, 147-49.
[199] Nicol 1988, 1-67; see also Jacoby 2009.

century, the Amalfitans were also an important mercantile presence as merchants in the central and eastern Mediterranean.[200] In the 960s, the Lombard diplomat Liutprand of Cremona mentions the presence of Venetians and Amalfitans in Constantinople as merchants, notes their service in the Byzantine armed forces, and complains that they are permitted to legally export certain categories of Byzantine silk textiles denied to other foreigners.[201] In the late eleventh century, the Venetians won major trade concessions from the Byzantine emperor Alexios Komnenos, who badly needed their naval help to fight off a Norman invasion of the empire; these concessions included exemptions from customs duties paid by Byzantine and other foreign merchants, a permanent *mitaton* inside the city, and the right to trade in all areas of the empire outside of the Black Sea.[202] Similar privileges were soon gained by other foreign merchants, who came to dominate much of the Byzantine Empire's trade and production. A strong Amalfitan presence in Constantinople, including wealthy merchants' houses, churches, and monasteries is attested by the eleventh century, while official Pisan and Genoese trade enclaves were established in the city by the early twelfth century.[203]

The privileges granted to the Italians in the later tenth and eleventh centuries coincided with a period of reduced or less effective commercial regulation, and a decrease in the

[200] Kreutz 1988, 104, 109-10; 1994, 351-52, 356-57; see also McCormick 2005, 544.
[201] Squatriti 2007, 248, 257, 266, 271-73; see also Magdalino 2000, 220.
[202] Geanakoplos 1986, 284-89; see also Oikonomides 1995, 234. Kahzdan and Constable (1982, 48-51) suggest that these concessions were little different from those given to other foreign groups in the tenth century, and that the detrimental effects to the empire's trade and the imperial government were due to the large volume of trade by the Italians and their greater organization, in contrast to the culturally individualistic Byzantines.
[203] Oikonomides 1995, 237-38; see also Magdalino 2000, 221-26; 2007a, 95-102.

government control of commerce seen in earlier centuries. Contemporary accounts seem to show concerted attempts by sellers to circumvent government control and taxation; for example, new markets were established away from customs stations on the Dardenelles and the Bosporus in order to avoid customs duties for shipping goods to and from Constantinople.[204] Michael Attaleiates' account of the shipping of grain to Constantinople was written as a protest against what he saw as excessive state control of trade.[205] Interpretations of total dominance of Byzantine maritime trade by Italian merchants in this period are likely exaggerated and based on the more abundant surviving records in Italian sources.[206] Documentary sources indicate continued activity of Byzantine traders, including long-distance traders. However, in the eleventh and twelfth centuries Italian merchants did come to control much of the Byzantine Empire's domestic trade and operated under fewer tax obligations and controls than Byzantine merchants. This caused resentment among the local population—in extreme cases leading to attacks on Italian merchant enclaves—as well as an erosion of the imperial control of commerce so apparent in the *Book of the Eparch* and earlier government regulations.[207] According to Laiou and Morrisson, the lifting of trade restrictions on foreign merchants likely benefited the many Byzantine merchants and producers, "But in the long run, the logic of the situation gave the Italians a larger share of the domestic trade, thus creating a situation where profit-sharing with the native merchant was no

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[204] Oikonomides 1995, 228-29.
[205] Magdalino 1995, 42-4; see also Kaldellis and Krallis 2012, 367-73, 507-9.
[206] Browning 1993, 109; see also Jacoby 2000a, 25-47; Laiou 1993, 79-92.
[207] Laiou 1993, 90-1.

longer necessary."[208] In spite of increasing competition from Italian merchants that would severely weaken the Byzantine state in later times, the eleventh century was a period of major economic prosperity.[209] A century and a half of largely victorious campaigns against the Arabs and Bulgars, which culminated in the conquest of the Bulgarian state in the early eleventh century by Basil II, left the Byzantine Empire in a strong position until the Selcuk invasion of Anatolia in the 1070s.[210]

The period described in the *Book of the Eparch* roughly coincides with the date of the Yenikapı 14 (YK 14) shipwreck. It was the last period in which the Theodosian Harbor played a significant role in Constantinople's maritime trade, as well as the last period in which this trade appears to have been effectively 'restrained' by the extensive government regulations of the Byzantine state. Most maritime trade was still in Byzantine hands, a state of affairs that gradually changed over the next two centuries into a less-regulated and more capitalistic domestic economy controlled at least partially by foreigners.[211]

These political and economic conditions affected all aspects of Byzantine maritime activity, including ship design and ship construction methods, and must be considered in the archaeological study of the Yenikapı shipwrecks. YK 14 was constructed under a unique set of economic, social, and political conditions. Based on evidence from

[208] Laiou and Morrisson 2007, 143-46.
[209] Laiou 2002e, 1150-156; see also Whittow 2008, 487-89.
[210] Angold, 1997, 3-11, 94-8; see also Laiou 2002a, 18-20.
[211] Oikonomides 1995, 229-238; 2002, 973-5, 979-80.

documentary sources, the large-scale but diffuse network of aristocratic and ecclesiastical estates, small landowners, and private merchants used large numbers of relatively small vessels to supply the capital with basic commodities. The technological and design features of the ships used for this trade, however, are almost entirely neglected in Byzantine documentary sources. YK 14 and the other Yenikapı shipwrecks are perhaps the best sources of evidence for how the ships involved in trade with Constantinople were built and used, as well as providing insights into why the sometimes idiosyncratic features of these ships were developed.

CHAPTER II

THE ARCHAEOLOGICAL CONTEXT, EXCAVATION, AND DOCUMENTATION OF YENİKAPI 14 (YK 14)

1) Introduction

Yenikapı Wreck 14 (YK 14) was discovered on 27 January, 2007, in the central part of the Marmaray Project zone at the Yenikapı excavations, approximately 25-30 meters west of Namik Kemal Avenue. Nearby archaeological features included an Ottoman period well and a later Byzantine burial, but the area of the shipwreck itself was not disturbed aside from some later medieval dock pilings which were driven into the hull in several locations (**Figure 2.1**). The ship rested in a stratigraphic layer consisting primarily of gray sand mixed with seashell and pottery fragments. Pockets of organic remains had also built up under sections of the hull some time after its sinking.

Figure 2.1: The YK 14 shipwreck site in March 2007, shortly before the beginning of its excavation. The plastic tape denotes the boundaries of the shipwreck. Note the later medieval dock pilings crossing the excavation area.

As with most of the shipwrecks found at Yenikapı, no clearly identifiable cargo, ballast, or items of ship's equipment were found in the ship's hull. The pottery sherds from the stratigraphic layer of the shipwreck were dated by archaeologists of the Istanbul Archaeological Museums to the late ninth or early tenth centuries C.E. (**Figures 2.2-3**).[212] However, preliminary analyses of a dendrochronological sample from the shipwreck site suggest a construction date earlier in the ninth century.[213] The scattered ceramics inside of the hull had clearly been deposited after the sinking of the ship. The artifacts excavated around the shipwreck included disarticulated ship timbers, wood fragments of uncertain origin and function, and fragments of ship's equipment, including two rope fragments, two pitch clumps used as waterproofing material, and two wooden rigging elements.[214]

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[212] Perinçek 2010, 208; see also Liphschitz and Pulak 2009, 168. Amphoras found in the wreck layer were similar in shape to Class 1 amphoras found on the ninth century C.E. shipwreck found at Bozburun on the southwest coast of Turkey, as well as Hayes' Type 47 and 48 from the Saraçhane excavations in Istanbul near the Yenikapı site (Bass 1974, 338; see also Hayes 1992, 72-3, Fig. 25:1). Some amphoras excavated above the shipwreck resemble Hayes' Type 54, especially Fig. 24:2-3, dated to the tenth century. A dendrochronology sample of the Bozburun shipwreck's keel was analyzed by Peter Kuniholm of the Aegean Dendrochronology Project and found to have been felled in 874. This date provides a terminus post quem for the construction ship, although the timber would have probably been left to season for a time before use (see Chapter VI) (Harpster 2006, 95). The production and distribution of this class of amphoras is still poorly understood, but they are usually found in ninth and early tenth century C.E. contexts in the Crimea, Balkans, Greece, Turkey, and southern Italy (Hocker 1995, 6, Fig. 5; 1998a, 4-5, Fig. 1; Hocker and Scafuri 1996, 5; van Doorninck 2002a, 902). Above the shipwreck layer, Günsenin 1 amphoras of the 'Ganos' type from Ganos on the Sea of Marmara are found; these are generally dated to the tenth to twelfth century C. E. (Günsenin 2009, 147-50; see also Dark 2001, 49; Vroom 2005, 94-5).

[213] Unpublished report by Peter Kuniholm, Brita Lorentzen, Charlotte Pearson, and Tomasz Wazny of the Aegean Dendrochronology Project, June 2013.

[214] For details of the rigging elements, see Chapter V; for the rope and pitch clumps, see Chapter VI.

Figure 2.2: A baulk left across the YK 14 shipwreck during its excavation in April of 2007 shows the nature of the stratigraphic deposits in the shipwreck: gray sand, with some bands of darker organic material, and scattered pottery fragments, mostly from broken amphoras. These are similar to deposits observed outside of the ship.

Figure 2.3: Detail view of the baulk left in the hull of YK 14 during excavation. Note that none of the pottery fragments are resting on the bottom of the hull, indicating that they were deposited in the hull some time after the sinking of the ship.

2) The Excavation, Field Documentation, and Dismantling of YK 14[215]

Archaeologists from the Istanbul Archaeological Museums uncovered the YK 14 shipwreck between 28 March and 21 April, 2007. Work began with the erection of a tent around the shipwreck site (**Figure 2.4**). A greenhouse-style sprinkler system was installed inside the excavation tent in order to keep the waterlogged hull timbers from drying out during the excavation; drying causes shrinkage and distortion in waterlogged timbers.

[215] The documentation methods used in the excavation and cataloging of YK 14 were adapted from those described in Volume I of the Serçe Limanı shipwreck final excavation report by Steffy and Matthews (Bass et al. 2004) and Chapter 9 of Steffy 1994.

Figure 2.4: YK 14 during excavation, showing the excavation tent, water hoses and sprinkler system, and medieval dock pilings in situ.

The sprinkler system was vital for preventing this damage to the hull, which necessarily remained exposed for several months during the excavation (**Figure 2.5**). During work hours when the sprinkler system was shut off, archaeologists sprayed the ship with a hose every few minutes in order to avoid damage to the wood from excessive drying. A sump was dug to the north of the shipwreck in order to drain excess water from the wreck pit. It consisted of a sump hole, into which a large, meter-deep wooden box was inserted to keep the surrounding sediments from collapsing. An electric pump for drainage was installed in the sump. Due to the drainage on the site at the time of the excavation, flooding of the excavation area by groundwater was not a significant problem in comparison to some of the other shipwreck excavation areas at Yenikapı. When necessary, water collecting inside the shipwreck was removed with a small, portable electric pump (**Figure 2.6**). After several weeks, green algae began to grow on the wood in the lowest area of the hull; this growth was successfully removed by the spraying of a dilute water/bleach solution on the wood by the Institute of Nautical Archaeology's (INA) head conservator Asaf Oron. Since it was used sparingly, this procedure had no adverse effects on the hull timbers.

Figure 2.5: The sprinkler system in use on YK 14.

Figure 2.6: An archaeologist from the Istanbul Archaeological Museums uses a small electric pump to drain water from the ship's hull.

Archaeologists excavated the hull using shovels, trowels, and running water directed through several water hoses. The overburden and sediment around the main hull area was removed primarily by workmen with shovels, while the excavators removed sediments in close proximity of the wreck with trowels, particularly during the excavation of the interior of the hull. Hoses were used for the delicate task of removing the last of the sediment around the ship timbers. A gentle water jet was used to loosen the sand, which typically flowed to the bottom of the hull where it could be scooped out with a trowel or by hand; outside of the hull, workmen would shovel the sand into wheelbarrows for removal from the excavation area. This method of excavation was used on all of the Yenikapı shipwrecks and is highly effective for uncovering hull timbers without damage. The use of water hoses for excavating is much safer than digging with trowels or shovels, although proper drainage of the excavation area is required and in some situations excavators should avoid using a strong jet of water, since it can damage soft and spongy archaeological wood or other organic artifacts such as rope. Luckily, the timbers of YK 14 were in excellent condition and delicate material such as rope was rarely encountered in the excavation area. During the dismantling of the ship, water hoses were also extremely useful for loosening the packed sandy sediments below the hull planking, which could then be excavated by hand; this method allowed the careful and safe excavation of timbers and artifacts under the hull even when they were difficult to see.

During the final stages of excavation inside the ship, a baulk was left in one section of the hull in order to record the stratigraphy inside the shipwreck. Because the sediments inside the hull consisted of dense, packed sand and the hull timbers beneath were quite solid, archaeologists excavating the hull were able to stand or crouch inside the hull during the early stages of the excavation. However, once this material was removed, working from inside the ship was no longer possible without damaging the hull timbers. Much of the excavation, recording, and dismantling work over the remainder of the excavation was conducted from around the periphery of the shipwreck or on trestles set up across sections of the ship (**Figure 2.7**). The shipwreck site was formally handed over to the Institute of Nautical Archaeology (INA) team under the direction of Cemal Pulak on 27 April 2007.

Figure 2.7: In order to work on the inside of the hull without damaging the hull timbers, trestles were set up across the shipwreck. Here, several archaeologists of the INA team work on the field documentation and removal of frame timbers from the hull (May 2007).

The surviving portion of YK 14's hull was 11.73 m long and 2.55 m in width, representing approximately one-third of the original surface area of the hull. The ship was constructed primarily from oak, along with several other hardwood species (See Chapters III and VI).[216] Like most of the Yenikapı shipwrecks, the relatively rapid burial of the hull in anaerobic sediments below the water table resulted in excellent preservation of the ship's timbers and other organic materials. The in situ remains of YK 14 were preserved on the starboard side of the ship to the approximate level of the ship's original waterline, corresponding to a maximum height of about one meter. Only a few timbers on the highest section of the ship shows any signs of shipworm (*Teredo navalis*) damage, a clear indication of fairly rapid burial of the surviving hull after sinking. Based on the stratigraphy and condition of the hull timbers, the ship almost certainly sank in a storm.[217] The upper section of the ship was most likely torn away during the storm itself or soon afterwards, although some exposed hull elements may have been destroyed through exposure on the sea bed over a longer period.

[216] All wood identifications are by Nili Liphschitz of Tel Aviv University's Forestry Department. A summary of the wood identifications from several of the Yenikapı ships, including YK 14, was recently published (Liphschitz and Pulak 2009); the significance of these results is also discussed in Chapter VI.

[217] According to Doğan Perinçek, YK 14 is one of up to 25 ships that were sunk in two great storms in the tenth and eleventh centuries. YK 14 sank in the earlier of these two episodes, in the late ninth or early tenth century, while the majority probably sank in a later storm in the late tenth century (Perinçek 2010, 208, Fig. 13, 210-11, 215). The absence of teredo worm damage on the hull timbers of several ships sunk in the later storm suggests that the hull remains of these ships were buried even more quickly than the YK 14 timbers (C. Pulak, personal communication).

Photomosaics and Total-Station Mapping

After the initial excavation of the shipwreck was complete, overall and detail photographs of the hull were taken, as well as detailed notes on construction features of the vessel. A photomosaic was made in Photoshop by INA archaeologist Sheila Matthews from a series of overview shots taken vertically from around the periphery of the wreck (**Figure 2.8**). The photomosaic photographs were not taken with a photogrammetry apparatus, and so are not suitable for obtaining detailed measurements of the wreck, but were intended for documenting an overall view of the ship's features and for producing preliminary site plans to assist with the documentation of the hull during the excavation.[218] An outline plan of the hull timbers based on the photomosaic of the wreck was produced by Matthews in Photoshop; this plan was used during the excavation for taking notes and making study diagrams (**Figure 2.9**).

[218] For the use of photogrammetry in the terrestrial excavation of a shipwreck, see Crumlin Pedersen 2002, 50-2.

Figure 2.8: Photomosaic of YK 14 by S. Matthews, April 2007.

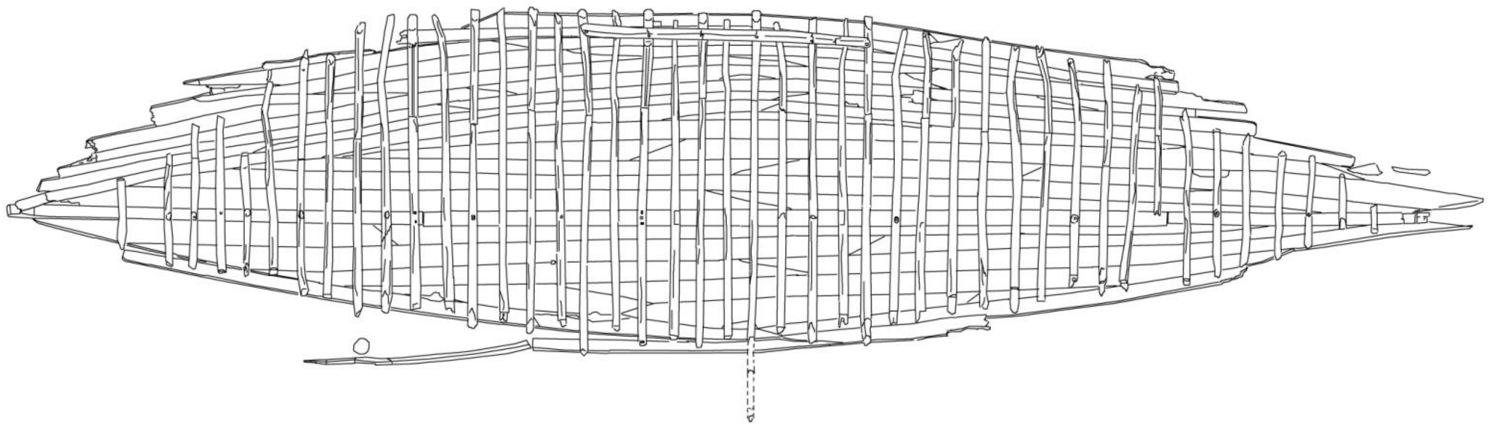

Figure 2.9: Sketch plan of YK 14 by S. Matthews, based on the photomosaic documentation of the shipwreck. This plan was used for notes and drawings during the total station scanning, excavation, and dismantling of the ship (April 2007).

Timber Labeling

After the photomosaic and outline plan of the ship were completed, the outline plan was used to assign labels to each timber on the wreck site. Planks were labeled with temporary plastic labels made with a Dymo LetraTAG label maker (**Figure 2.10**).

Figure 2.10: Plastic Dymo labels on a hull plank. The labels were fastened to the plank using pins made of stainless steel wire. These labels were replaced with embossed stainless steel labels during cataloging in order to prepare the timbers for conservation treatment in PEG (polyethylene glycol).

These labels are white with black text, a useful color combination for timber labeling on shipwrecks because the label text is fairly legible in detail photographs of the hull. After the excavation, the plastic Dymo labels were replaced with embossed stainless-steel labels made with a Rhino M1011 label maker in preparation for conservation treatment.[219] Both types of labels were fastened to the timbers using stainless-steel wire pins.

Unlike some shipwrecks, there were no obvious indications of YK 14's midship frame or of the bow and stern of the vessel; the original hull was double-ended, and there were no indications of the bow and stern locations from the ship's equipment (for example, the positioning of anchors in the bow). During the excavation, one end of the wreck was arbitrarily designated the 'bow' (although later analysis indicates it was the stern); frame positions were numbered from 1 to 52, beginning from the 'bow.' Frame positions were identifiable by the presence of the actual frame or by rows of frame-fastener holes and other evidence in the surviving hull planking. In other respects, the timber labeling system was adapted from that used in the excavation of the Serçe Limanı shipwreck.[220] Floor timbers, or frames which cross the keel, were designated by the letters 'FL', followed by the timber number, while futtocks were designated by the letter 'F' and the timber number. The three keel timbers were designated as 'Keel' 1, 2, and 3, from the 'bow' to the 'stern.' Hull planks were designated by numbered 'port' strakes (PS 1, 2, etc.) or 'starboard' strakes (SS 1, 2, etc.), numbered consecutively starting from the keel, with a second number designating the plank in the strake from the 'bow' to the 'stern' (PS 1-1, 1-2, etc.). Every fifth frame position was labeled on the hull planking. Several labels were added to planks and frames, either where breaks occurred or where they

[219] INA Conservator Asaf Oron found that the text on the Dymo labels did not survive when heated in polyethylene glycol (PEG), the preservative agent that is being used to conserve the timbers from four of the Yenikapı shipwrecks at the Institute of Nautical Archaeology's Bodrum Research Center (BRC). PEG is corrosive to iron or mild steel but does not react with stainless steel (Hamilton 1999, 25).
[220] See Steffy 1994, 194-98, and Bass et al. 2004, 76-9.

might potentially occur; these were indicated with a slash followed by a number, with the lower numbers being closer to the 'bow': for example, 'PS 1-2/1, 2, 3', etc. Some irregular planks or repair planks were labeled 'A' or 'B' to denote the fact that they are stealers or dropstrakes, repair pieces, or otherwise unusual; these include SS 6-2A and SS 5-2A (repair planks), PS 5A, PS 10A, and PS 10B (stealers and dropstrakes), and PS 9A (a filler piece, probably inserted to repair a split in the plank during the initial construction of the ship). During the course of the excavation, it was found in several instances that separate planks timbers were accidentally labeled as parts of the same plank: due to the heavy pitch coating inside the hull, it was sometimes difficult to distinguish cracks or breaks in the planking from scarf seams. In these cases, the original numbering was kept for the sake of consistency in recording the ship even though the pieces themselves are separate timbers (e.g., SS 1-1/1 and SS 1-1/1A-5; PS 2-1/1-2, PS 2-1/3, and PS 2-1/4-6A, etc.). A single stringer, designated ST-1, was found on the starboard side at the level of the waterline.

Twenty-four disarticulated ship timbers and worked wood fragments were found during the course of the excavation. These were given 'UM' designations, for 'Unidentified Member,' and numbered in the order that they were discovered. This category includes partial and complete planks, frames, and unidentified timbers which may not necessarily come from YK 14's hull. In some cases UM timbers cannot be definitively identified as hull timbers at all; generally, the excavators erred on the side of caution and gave a separate label to any timbers that could have originated from the hull. Most of these timbers appear to be ship timbers from YK 14 or another vessel, although several are almost certainly harbor debris. In a number of cases, a 'UM' timber was found to join another hull timber in the main body of the shipwreck. The UM designation for these pieces was canceled and the piece was relabeled to indicate its correct designation: for example, UM 16, a floor timber found under Keel 3 during the excavation, was found to be FL 47, a floor timber which was torn from the hull during the sinking of the ship. In another case, frame fragments UM 10 and 11 were found to join a broken end of floor FL 27; these UM pieces were therefore relabeled as parts of FL 27.

A separate labeling nomenclature was developed during the Yenikapı excavation to refer to the different faces of UM timbers, since their position on a vessel was not necessarily certain. The side of the timber that was found face-up on the excavation site or exhibited the most distinctive features was designated as Face 'A', while Face 'B' was the opposite face. In the case of frames, the inner and outer faces could easily be determined; similarly, the inner and outer faces of UM plank timbers could sometimes be determined as well based on frame fastener features or the thickness of pitch deposits. If there was no clear evidence for the orientation of the third and fourth faces of a UM timber in a ship's hull, these faces were labeled Face 'C' and 'D,' Edge 'C' and 'D', in the case of planks, or End 'A' and End 'B' for the ends of timbers.

Smaller pieces such as scarf keys or coaks were labeled based on their position in the ship, for example "Keel 2/3 scarf key" or "PS 2/3 seam coak, between FL 27-28." This labeling was adequate for the small number of miscellaneous ship finds not covered by the 'UM' designation.

Total Station Scanning

The shipwreck was mapped in situ using a total station and technicians provided by the surveyor Sadık Demir of İmge Harita İnşaat. Demir's team worked under the direction of Sheila Matthews in mapping the shipwreck between 28 April and 10 May, 2007, with additional mapping of planking features after the removal of the frames from 1-6 June, 2007. The total station is an electronic theodolite that measures distances using an infrared or laser light beam and stores measurement data.[221] Total station mapping requires the recording of three stationary datum points set up on level tripods, whose positions are measured by the total station device itself. The total station measures the exact distance from the datum points to specific points on the shipwreck using an a built-in electronic distance measuring device (EDM), which measures distances from a datum point using a laser. The laser can be fired at either a specific point indicated by an assistant with a pointer, or with a reflector with an embedded level, which is used for points that are blocked from the EDM operator's direct line-of-sight. (**Figure 2.11**). Each point is assigned a set of x-y-z coordinates by the total station. Matthews developed a set of charts, sometimes supplemented by sketches in more complex areas, to identify the specific points or groups of points as features of the shipwreck, such as timber edges, plank seams, and fasteners (**Figure 2.12**).

[221] Kavanagh 2006, 51, 205.


Figure 2.11: The tripods around the ship serve as datum points for total station mapping of YK 14.


Figure 2.12: Total station mapping in progress.

These notes and sketches were later used to plot the total station data in three dimensions using the RHINO NURBS modeling program to 'connect the dots' and create a 3-D scale digital model of the shipwreck. This model was then used to create accurately-scaled site plans and cross sections of the ship (**Figure 2.13**). Errors or ambiguous areas could be clarified by re-measuring them, sometimes during later stages of dismantling the hull. During the excavation of YK 14, total station mapping was executed in two stages: first, the complete shipwreck as found was measures, while a second stage of measuring occurred after the frames were removed, in order to record planking features such as frame fastener holes that were obscured by the frames.[222] The RHINO 3-D model of the hull was used for producing accurately scaled preliminary site plans and cross sections of the hull, and had a variety of uses in the later reconstruction of the hull.

[222] Due to the relatively simple interior design of the hull, this task was simpler than the mapping of some of the other Yenikapı ships. For example, YK 11 was mapped in four layers, due to the large number of UM timbers overlaying the wreck and the presence of internal timbers fastened over the framing, such as stringers, ceiling planking, and stanchion blocks.

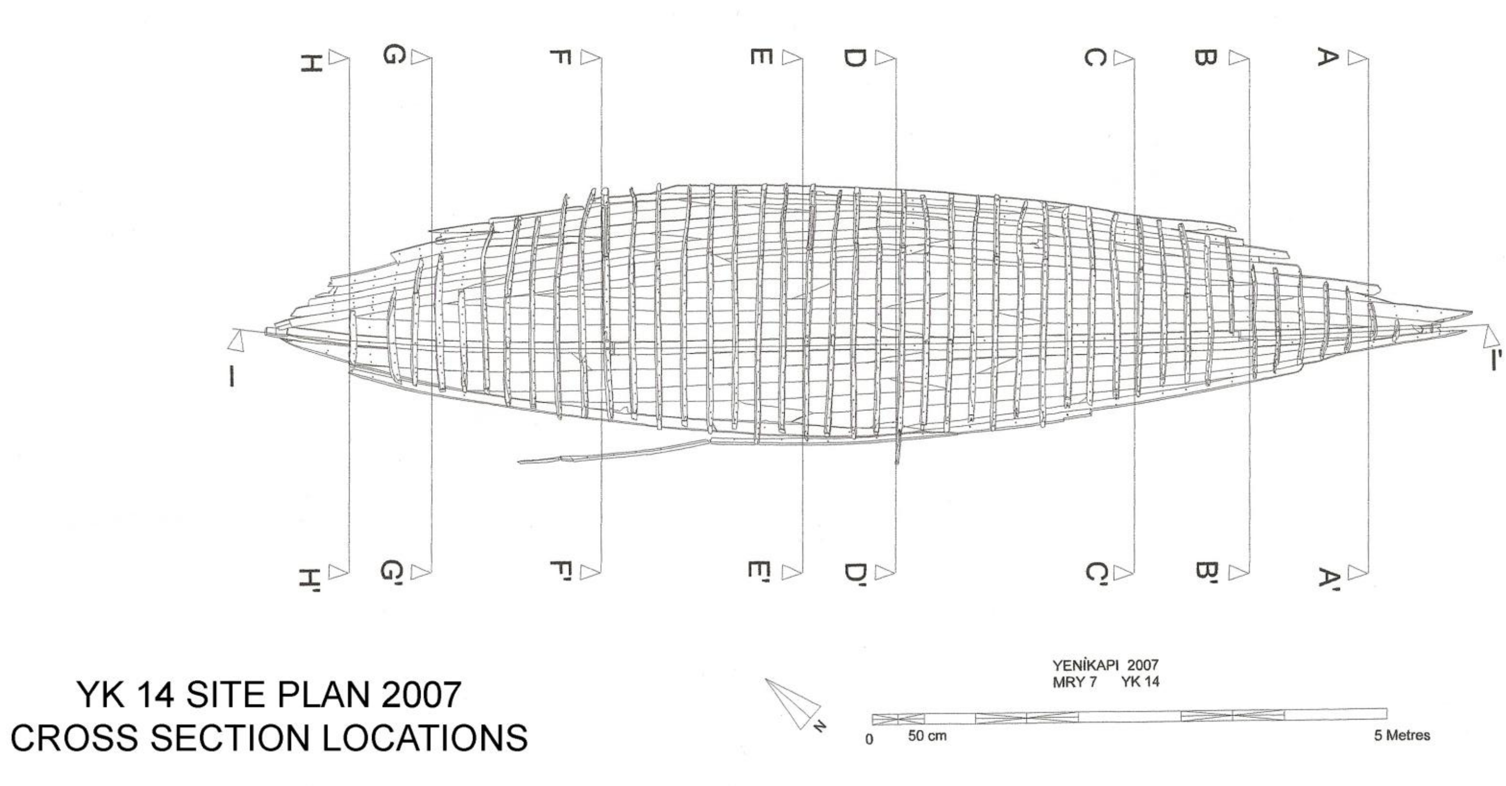

Figure 2.13: An overview of the total station plan of YK 14, developed using RHINO 3-D modeling program, showing the locations of cross sections taken for a preliminary excavation report (See Chapter III for the in-situ cross sections of the ship).

Total station scanning combined with 3-D modeling produces a highly accurate digital representation of the shipwreck's shape as found on the wreck site. This is particularly important for recording the framing and planking curvatures before dismantling the hull. During the dismantling process, breaks in the weakened, waterlogged timbers inevitably occur, and the curvature of bent planking timbers may settle and change shape. Total station scanning allows the accurate documentation of the timbers' shapes before their removal. Distortion of the hull, which can be quite subtle in some areas, may also become clearer once the total station data is plotted. Although many of YK 14's hull timbers retained their original form, some areas of distortion were clearly evident; planks sprung out of place during and after the wrecking of the ship, the keel and some of the frames had broken and shifted, and the weight of 1100 years of sediment and debris had twisted and distorted certain timbers. For this reason, the total station mapping of the shipwreck is only a starting point for the reconstruction of the hull, and the shapes of individual timbers may be modified on the ship reconstruction based on other evidence. Also, during the initial total station scanning process, some details are inevitably missed, such as fastener holes and plank or scarf seams obscured by pitch. Buried features, such as the outboard section of the keel timbers, may also not be accessible during the total station mapping and must be added to the reconstruction using information from scale drawings created after the dismantling of the ship. Such details were added later after 1:1-scale drawings of the hull timbers were completed; essentially the two sets of data—the total station data and the 1:1-scale drawings—are used to check each other. The 1:1-scale drawings are generally better for recording the details of the hull timbers during and especially after the excavation, while the total station data is most useful for recording the locations, shapes, and orientations of the timbers as found.

Dismantling the Hull

The hull of YK 14 was dismantled between 10 May and 27 September, 2007. After total station mapping of the hull was completed, dock pilings in the excavation area and exposed UM timbers from the shipwreck and the surrounding area were removed first. Then, between May 10 and June 12, the frames were removed after the completion of preliminary documentation. The field-recording process was similar for all frame timbers, but the procedure for frame removal varied depending on the size and condition of the timber. Although most of the hull timbers had firm surfaces, due to their waterlogged state they had lost much of their structural strength and required careful handling. Small timbers, such as futtocks, could be handled by a single person using a wooden board or pallet for support of the piece if necessary. This was sufficient for the futtocks and small floor timbers from either end of the hull. The larger floors required two or more excavators to lift and move using pallets or custom-built wooden molds.

Before removal from the hull, individual frames were first photographed in situ, then a worksheet for the individual piece was prepared and plank-seam locations on the frame were marked with pins made from stainless steel wire. These markers were vital for the cataloging and reconstruction processes, since they served as reference points for the position of the frame in the hull. Although hard areas of the timbers' surfaces were sometimes encountered, in most cases the stainless steel pins could be easily pressed into the relatively soft, waterlogged wood. After the initial preparations were made, the frame was separated from the hull by cutting or breaking the fasteners securing it to the planking. This was most easily done by inserting a box-cutter's blade in the gap between the frame and the planking to cut through the treenails. Although nail concretions which were much harder than the treenails were encountered on some of the other Yenikapı shipwrecks, iron-nail concretions on YK 14's hull were not particularly solid and would crumble after some probing with a box-cutter blade.

To remove large frames, first a trestle was set across the ship next to the location of the frame to be removed. After the frame fasteners were cut or broken through, the fasteners or their holes on the outer face of the frame, as well as on the planking, were cleaned and marked with steel pins; the outer face of the frame and the fastener holes in the planking at that position were then photographed (**Figure 2.14**). These photos were used for reference later during the cataloging and reconstruction stages.


Figure 2.14: A section of Frame timber FL 18’s outer face after removal from the hull, with plank seams and fasteners marked with pins. Fasteners were marked in order to match the fasteners on the frame to the corresponding ones on the planking after dismantling: yellow pins were used for treenails and blue pins were used for nails.

Each frame position on the planking, as well as the outer faces of the removed frames, was sketched on a worksheet to record the number of fasteners on each strake, their approximate positions, and the approximate locations of plank seams (**Figure 2.15**). The ‘frame worksheet’ and pre- and post-removal photographs of a frame were important later in the cataloging process for correctly reconstructing the positions of timbers in the hull. The correct matching of fasteners on the frames to those on the planking was sometimes difficult due to closely-spaced or overlapping fasteners and ‘extra’ fastener holes that sometimes occurred in areas that were later repaired. The frame sketches and worksheets were very useful in locating the corresponding fastener holes in the frames to those on the planking during post-excavation cataloging.[223]

[223] In order to save time during the excavation, we refrained from using more comprehensive individual worksheets for the timbers, as had been done on some of the other Yenikapı shipwrecks. Excavation notes were instead registered directly into an excavation notebook. Although this approach was adequate, the

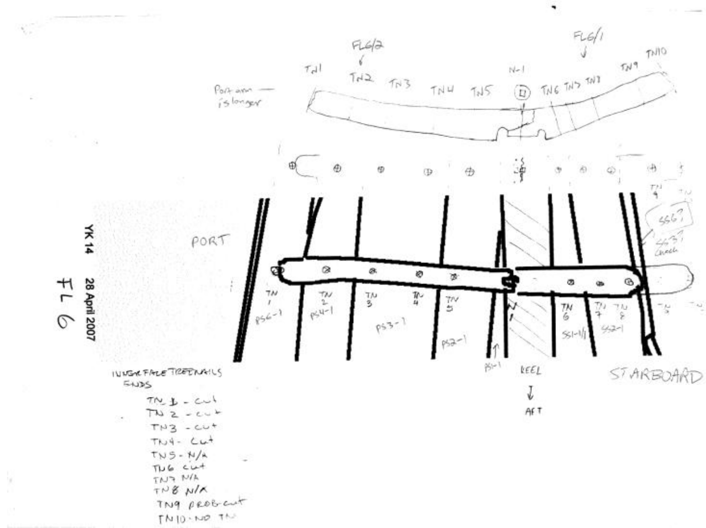

Figure 2.15: Example of a frame fastener sketch used for recording the exact position of a frame timber in the hull, the fasteners used (and not used) for securing the frame timber to the planking, approximate plank seam locations, and other important context information.

After the documentation of a frame and its corresponding planking fasteners was completed, frame timbers were packed in wooden crates lined with 2.5 cm-thick foam sheets in preparation for transport to the Institute of Nautical Archaeology's Bodrum Research Center (BRC) for further documentation and conservation treatment (**Figure 2.16**). The crates for frames were made in two sizes to accommodate different-sized frame timbers: 2.5 m long, 82 cm wide, and 20-25 cm high for large frames, and 2.43 m long, 50 cm wide, and 18-20 cm high for smaller frames. Usually, several frame timbers could be packed in a single box, and smaller foam pieces were often packed between the timbers to prevent damage while in transit. This was generally sufficient for those frame timbers that did not have significant curvatures in more than one dimension.

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inclusion of basic dimensions and other notes on individual worksheets during the excavation is preferable from an organizational standpoint.


Figure 2.16: Frame timbers in a foam-lined crate awaiting packing and shipment to the INA Bodrum Research Center.

However, large, curved floor timbers required additional reinforcement in order to preserve their original shape and prevent breakage during the dismantling process. Many of these large floor timbers were 2.0-2.5 m long, irregularly shaped, and particularly weak beyond the turn of the bilge. In order to remove these large pieces, molds of wood and polyurethane were constructed before the cutting of the fasteners connecting the frames to the planking. First, a wooden mold base made of fastened pine boards matching the curvature of the floor timber was cut using a jigsaw; then, the pieces were fitted against the interior of the hull at the frame to be removed to ensure that the mold base was of the correct shape (**Figures 2.17-19**). The frame fasteners were then cut, and the timber was detached from the hull and propped in place with sandbags; the assembled mold base was also propped in place as closely to the floor timber as possible. Plastic ties were inserted through the space between the floor timber, the mold base, and the planking so that the floor could later be tied to the mold; strips of foam were added between the ties and the frames to protect the frames' surfaces. In order to protect the hull's interior surfaces from any stray polyurethane drops, a layer of plastic was inserted between the floor timber and the planking. Two layers of aluminum foil were inserted into the space between the mold and the floor timber in order to prevent the polyurethane foam from adhering to the floor timber. The polyurethane was then injected into the gaps between the mold and the frame timber and allowed to harden. Finally, the plastic was removed; the plastic ties and were used to fasten the floor timber to the mold and the floor timber was removed from the ship.

Figure 2.17: Polyurethane foam was injected into the gaps between a floor timber and the wooden timber mold. The floor timber itself was wrapped in two layers of aluminum foil to prevent the polyurethane from adhering to the floor timber, while the plastic was spread between the outer face of the floor timber and the hull planking.

Figure 2.18: A floor timber being prepared for removal from the hull. After the polyurethane hardened, the floor timber was tied to the frame mold with plastic ties and lifted from the shipwreck.

Figure 2.19: Two floor timbers on molds. The timber on the trestle in the foreground is still being documented, while the timber behind it is secured to its mold and is ready for packing.

This method proved quite successful for removing large frame timbers from the hull and transporting them to the Bodrum Research Center safely. The molds were very convenient for moving the frames during the excavation and later documentation at the BRC. They also proved particularly useful during the creation of 1:1-scale drawings of the different faces of the frames, since the mold kept the timber at the same orientation throughout the drawing process. In all, 11 of the 45 floor timbers from the ship were removed with these molds.

Documentation and Removal of the Hull Planking

After all of the frames were removed from the ship, additional total station scanning of the hull planking was completed and planking features previously obscured by the hull's frames were photographed. The inner surface of the hull planking was then drawn in situ on clear PVC film in preparation for their dismantling. In situ drawing of the planking involves tracing significant features on the hull planking before removal, such as fastener locations, areas of damage, tool marks, frame impressions, and caulking and pitch deposits observed on the inner faces of the planks. The drawings also record the positions of hull planks in relation to each other; this serves as an additional set of data to check against the total station mapping and provides a detailed record for unusual features in the hull, such as areas repaired with replacement planks, pitch and caulking features, or areas damaged by dock pilings. After the conclusion of the excavation, high resolution scans were made of these 1:1 in-situ drawings.

The planking drawings were produced in two stages: first, the port side planking in June 2007, and, after the starboard side planking was removed, the starboard side planking in July 2007. Whenever possible, the planking was traced from around the edges of the shipwreck, but in both drawing periods much of the drawing was done from wooden trestles placed over the wreck (**Figure 2.20**).[224] The PVC plastic was cut into lengths 90

[224] The in situ plank drawings were completed in a single period for the first six wrecks excavated by the INA team at Yenikapı (YK 1, 2, 4, 5, 14, and 24). While completing the drawings in a single period was suitable for recording some of the wrecks, such as YK 24--a small vessel--and the galleys YK 2 and 4, whose planking was easily accessed once the frames were removed, this method presented more of a problem on YK 14. While drawing the starboard side, rapid flooding in the lowest part of the ship, as well as sand and other debris washing into the bilge from treenail holes in the planking, made observing and

cm wide and a maximum length of 6.0 m long, as they are the maximum dimensions that could be scanned efficiently through a large-format scanner; wherever possible, shorter PVC sections were preferred for ease of handling, and excess PVC portions not needed for tracing were cut off. Drawings were made to overlap so that no areas of the planking were missed and the relationship between the drawings could be reestablished after the dismantling of the hull.

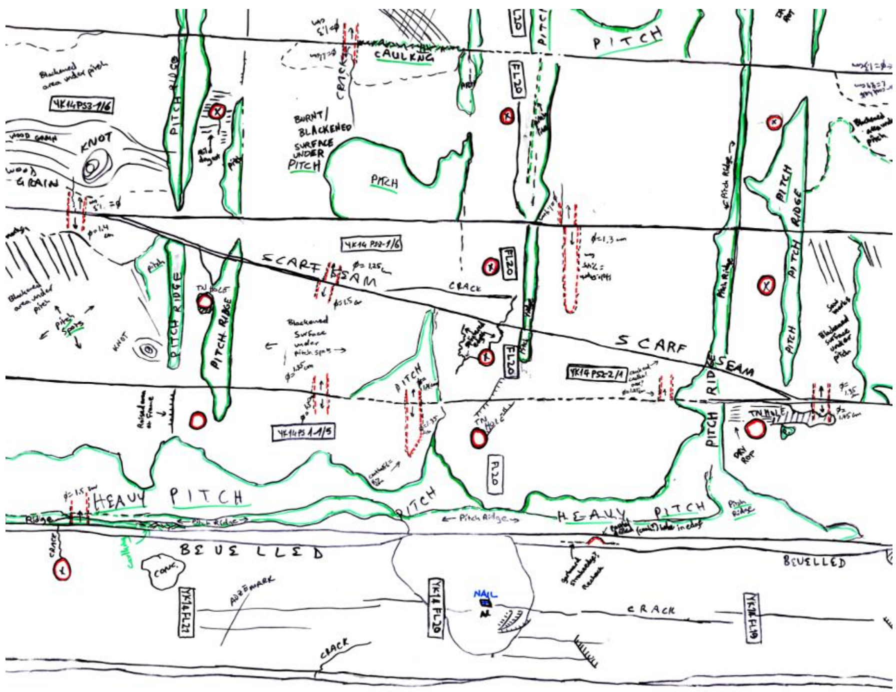

Figure 2.20: A section of in situ 1:1 planking drawings made during the excavation. The drawings are used primarily to record the context of the hull timbers in relation to each other as well as details that are not necessarily recorded during the total station scanning.

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tracing the details of the hull planking rather difficult in the lowest parts of the hull. For YK 23 and YK 11, the practice was adopted of drawing several strakes on 90 cm-wide plastic, removing the drawn strakes, (usually two or three strakes), and then drawing the next section. This method was far more efficient in terms of time and comfort than drawing from a trestle placed over the ship, and allowed for greater accuracy as well: the lowest sections of the hull could be drawn last, when bailing or draining water pooled in the hull is easier.

After the in situ drawing of the hull planking was completed, the INA team prepared for the dismantling and removal of the remaining hull planking. This was by far the most difficult stage of the excavation logistically, requiring the removal of several dozen three- to seven-meter-long intact planks and keel timbers, in addition to smaller pieces. Moreover, a large number of hull planks were curved, and therefore required custom-built molds in order to be removed. Smaller planks or planks without a molded curvature could be readily removed and placed in flat-bottomed timber boxes, sometimes after being tied to a board or small pallet for ease of handling.

The molds for curved planks were built by measuring the curvature of the pieces, either by taking offsets by hand or by the preparation of a diagram for the construction of the mold based on total station data of the mapped hull. Since there was typically a margin of error using either method, (often due to the 'twist' of a plank closer to the endposts of the vessel), 2.5 cm-thick foam was fastened to the mold surface in order to cushion and support the plank. The foam also provided significant friction, which prevented the planks from sliding off the molds. The timber molds were built with a base of 5 x 10 cm beams, onto which the upright supports for the mold were fastened at specific intervals (**Figure 2.21**). This method of construction was time-consuming and often involved some improvisation, but overall it proved very effective for preserving the timbers intact, and for allowing them to be moved with relative ease (considering their size), both on the excavation site and during later documentation at the BRC.

Figure 2.21: Detail of a plank mold constructed for a curved plank during the excavation.

After a plank mold was assembled and pre-removal photographs of the plank were taken, the sediment under the plank to be moved was excavated with a water hose and the excavated gap was filled with plastic sandbags. The mold was then positioned in front of the plank to be moved. Because of the presence of edge fasteners called coaks[225] connecting one planking strake to the next, the plank was first pulled away from the ship several centimeters before it was raised and placed on the plank mold.[226] Plank removal involved the participation of the INA team and any of the Yenikapı site archaeologists

[225] Definitions for nautical terms are listed in Appendix B.

[226] Occasionally individual coaks were cut beforehand, especially at scarf ends or other areas where they would not separate easily or where attempts to separate the planks in this fashion were likely to cause damage to the hull planks.

and workmen available in the area at the time; often a large plank required eight or ten individuals to lift onto a mold, and two to four to move the mold with the plank. The plank's previously-hidden inboard edge was then photographed, and additional catalog notes or additions to the in-situ 1:1 drawings were made as needed. Caulking as well as broken and intact coaks were usually sampled after the removal of a plank to avoid losing the material during subsequent handling of the molds. Wood samples were taken from each individual timber for species identification purposes, and caulking, pitch, and botanical remains were sampled throughout the excavation and post-excavation documentation for later analysis.

After a plank was removed and placed on its custom-built mold, it was secured to the mold with plastic tape and covered with a sheet of 2.5 cm-thick foam, which protected the plank by keeping moisture in; then, the plank-mold assembly was placed in a wooden crate built for this purpose. The crates were transported to concrete freshwater storage tanks on the site until shipment to INA-BRC could be arranged (**Figure 2.22**). The crates required weighing down with stones and bricks to prevent them from floating and capsizing, but after several months to a year in the water storage tanks, most timber crates were no longer buoyant and the weights could be removed.

Figure 2.22: The moving of a large plank box from freshwater storage tanks at the Yenikapı site to a cargo truck bound for INA's Bodrum Research Center (BRC), January 2008.

Dismantling a shipwreck hull provides several significant advantages over removing shipwrecks in one piece. Although groups of up to 20 archaeologists and construction workers were sometimes needed to assist in removing large timbers from the hull and for carrying the timber crates, heavy equipment was not necessary for removing planks from the site. Dismantling a ship reveals numerous construction details that are likely to be missed if the hull is removed intact, particularly if the vessel is built using shell-first methods, as was the case with YK 14. Dismantling of the hull vastly simplified the documentation process as well as the transport and storage of the timbers after the excavation was complete.

3) Post-Excavation Documentation in Bodrum, Turkey: 2009-2012

After the excavation and dismantling of YK 14 was completed in September 2007, the ship's timbers were transported to the Institute of Nautical Archaeology's Bodrum Research Center (BRC), in Bodrum, Turkey, where four shipwrecks from Yenikapı have been undergoing documentation and conservation treatment since 2009. YK 14's hull timbers were fully documented by the author over 27 months, between May 2009 and August 2012, in two main periods of research (May-August 2009 and June 2010-August 2012). Drawing and cataloging work on the timbers was conducted six days a week for the entire research period. The work facilities included the Hethea Nye Wood Conservation Laboratory at the BRC, where the smaller timbers from the ship were drawn and cataloged, and a pair of 27 metric ton-capacity (30-ton) outdoor wet-storage tanks on the BRC's grounds where larger timbers, primarily long planks and keel timbers, were recorded. The timbers are kept in freshwater storage tanks in both locations; a borax/boric-acid solution was added to the water as an algaecide.

The outdoor storage tanks are also designed as treatment tanks for conserving the timbers in Polyethylene Glycol (PEG), a water-soluble wax commonly used for the preservation of waterlogged wood and other organic materials found on archaeological sites. The outdoor tanks supplement the laboratory's smaller PEG tanks (approx. 10 cubic meter capacity), which are used for the conservation of smaller or more fragmentary shipwreck timbers. As the ship timbers were deposited in a waterlogged environment, they are extremely well preserved. However, since the cellular structure of the wood also degrades after extended periods of burial in waterlogged sediments, drying the timbers without preventative conservation treatment will cause extensive shrinkage and distortion. PEG bulks the cellular cavities and strengthens the cell walls of the wood so that they do not collapse when the timbers are dried.[227] The shipwrecks are conserved in PEG after the completion of the documentation process. If the maximum amount of information is to be obtained from shipwreck remains and the timbers are sufficiently well preserved to be handled frequently, documentation should occur before PEG treatment; PEG can obscure potentially significant surface details such as tool marks and guide marks made by the shipwrights during the construction of the ship.[228]

Shipwreck-reconstruction studies require detailed documentation and cataloging of each hull component. The methods used in documenting YK 14 are based primarily on those developed by researchers working on the excavation of shipwrecks in the Mediterranean and Baltic Sea since the 1960s, in particular by van Doorninck and Steffy of INA.[229] Each hull component from the ship is drawn at 1:1 scale on clear plastic or acetate. The methods and degree of detail desired for recording each category of timber varies. Typically three to four faces of frame and keel timbers are drawn, depending on the degree of noteworthy detail on each face; with these timber categories, 1:1-scale cross sections were drawn as well using drafting triangles and rulers modified into tools for

[227] Hamilton 1999, 22-5.

[228] Mor 2003, 180. In the case of the Ma'agan Mikhael shipwreck, much of the timber recording was done after conservation in order to avoid damage to the soft wood (Kahanov 2011b, 164). In the case of YK 14 most of the hull timbers were in very good condition, so the risk of serious surface damage to timbers was minimal.

[229] Bass el al. 2004, 73-9, 123-26, 153-69; see also Bass and van Doorninck 1982; Steffy 1985a; 1994; Crumlin-Pedersen 2002, 49-63; Kahanov et al. 2003.

taking cross sections.[230] Curved timbers such as the frames were first drawn using permanent markers on a glass pane; when these drawings were complete, a 'clean' final copy was made by transferring the drawing on the glass to PVC plastic, and colors and other notes were added later.[231] Most of these drawings were made with the glass positioned over the timber (**Figure 2.23**). However, the curvature of many of the 'L'- or 'V' shaped floor timbers from YK 14 were too great to record in this manner, as it was too difficult to prop such large frames in this way without damaging them. For these timbers, the glass was set up at a 90º angle from the face being drawn, and lights on extendable arms were clamped to the table over the glass (**Figure 2.24**).[232] The positioning of the lights used in this type of scale drawing is crucial; the reflection of the drawer's pupil in the glass ensures that the feature he or she is tracing is perpendicular to the glass. For this reason, two lamps with adjustable armatures were used for each drawing. This method is quite effective, and drawings made in this way which were checked against measurements of the actual frame timbers and were found to be accurate.[233]

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[230] For planking catalogs, measurements of plank thicknesses and edge beveling were considered to be sufficient based on their relatively simple cross-sectional shapes.

[231] Color coding on the 1:1 drawings is as follows: green for pitch and caulking, red for treenails, drilled holes, and mortises, and blue for nails, burnt/blackened areas, or caulking iron damage on the wood.

[232] INA archaeologist Orkan Köyağasıoğlu perfected the apparatus and drawing techniques for drawing the inner and outer faces of curved floor timbers from the YK 5 wreck during 2008.

[233] Two potential problems can be encountered using this method. First, drawing in poor lighting conditions makes it difficult to discern edges and other details on the frame timbers. Second, frame timbers with broken 'long arms' can be difficult to reconstruct correctly, particularly in rejoining the broken pieces in the exact same positions on both the inner and outer faces. For these parts of the drawings other data such as total station plans, fastener holes in the hull planks, etc., were relied upon to correct the errors. The frame molds used during the excavation were often very helpful in drawing the inner and outer faces of these pieces, since the mold kept the frame in the same position for both drawings and produced very uniform results. Whenever possible, 'side-drawn' timbers, which had not been transported on a frame mold, were set up on a wooden pallet. The pallet could be rotated so that both faces could be drawn in a

Figure 2.23: Keel timber Keel 1 set up for drawing on glass in the wood conservation laboratory at the BRC.

Figure 2.24: The outer face of FL 20, a large, curved floor timber supported on a frame mold, being drawn directly on glass.

single work period, thus avoiding potential errors from removing the timber from the table and setting it up again for drawing at a later time.

Hull planking was drawn by laying the plastic sheet directly over the plank and tracing the details on it. This drawing method was preferred because the planks were originally flat, their original curvatures were already recorded using the total station, many of the planks were too large to effectively be drawn using glass, and the primary purpose of drawing the planking at 1:1 scale was to record fastener locations and surface detail rather than their curvature, which is preserved by the frames. Although the hull planks were originally drawn in situ during the excavation before the hull was dismantled, the in situ drawings were found to be useful primarily for recording the relationship between the timbers and for features that were later removed during the dismantling, such as pitch and caulking repairs. In many cases details were missing on the in situ 1:1 drawings such as the locations and depths of edge fasteners, fastener holes, and the details and exact outlines of scarf seams, particularly in areas where the seams were obscured by heavy pitch or caulking, which frequently occurred in YK 14's heavily-pitched hull. Some areas of the planking were also drawn very quickly during the excavation because of flooding problems encountered in the hull. Separate drawings for the hull planks that were made at the BRC after the excavation are far easier to handle than the generally large, 1:1 in situ drawings, and a greater degree of detail, especially those of features found under the layers of pitch in the planks and additional labels that were added due to breaks on the timbers, could be conveniently added to the post-removal drawings.[234] The

[234] The planking catalogs were begun by adding details to the 1:1 in situ drawings, but the addition of post-excavation detail required excessive erasing and cleaning of the drawings to be practical. Another factor was that the large width and size of the 1:1 in situ plank tracings (most were 6 meters long and 90 cm wide) made them extremely difficult to work with inside the timber tanks, where all work on the larger planks and keel timbers necessarily took place. The markers used for drawings are unusable on wet acetate, and it was difficult to keep the large drawings dry while working in the timber tanks.

details on the 1:1-scale drawings made after the excavation were, therefore, considered to be the final versions of the plank drawings. Drawings on plastic film are also well-suited to working directly with the timbers; they are not damaged by water and are easily cleaned, an important consideration since the larger hull timbers were traced just above the water level in the timber storage tanks, and the timbers themselves needed to be kept as wet as possible.

Planks were typically drawn only on their inner faces, although in some cases part or all of the outer face was also photographed or drawn if it was easily accessible and significant features were visible. For planking, thickness and edge-beveling measurements are usually sufficient rather than 1:1-scale cross sections. Stringer ST-1 was drawn on one face using glass, but 1:1-cross sections were recorded as well. Methods used to draw UM timbers varied greatly depending on the piece and its features. All were drawn on one face and photographed on all four faces, while larger or more distinctive timbers were recorded in more detail.

After completion, the timber drawings were scanned at a high resolution both for archival purposes and also for the ease with which they can be resized at different scales and adapted for use in 3-D modeling programs such as RHINO. These drawings were used as the basis for the creation of ship's lines and other scale drawings as well as three-dimensional scale models, and offer an expedient alternative to other methods of digitally recording ship timbers (see Chapter IV).[235]

Scale drawings of timbers are supplemented by detailed notes and measurements for a timber catalog of each piece, overall and detail photographs of the timber's features, and sampling of wooden components and other materials for later identification and analysis. During the cataloging process, significant features such as the condition of the timber, details of wooden and metal fasteners, and tool marks and shipbuilder's guide marks are recorded. While recording these features in detail is time-consuming, it is particularly important for documenting ancient and medieval shipwrecks since the methods used in their construction are not fully understood. Catalog worksheets were developed for the cataloging of timbers and were kept in polyethylene sleeves clipped to a clipboard case; the clipboard storage case was used for keeping calipers and other measuring tools, dental picks, pencils and markers for 1:1-scale drawings, and catalog worksheets.[236] The plastic sleeves and the clipboard case were vital for efficiently cataloging hull timbers, especially large timbers kept in the outdoor wet storage tanks that could not be easily removed.

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[235] For other methods of digital recording of ship timbers such as the use of the articulated FARO arm, see Nayling and Jones 2012 and Ravn 2012. The use of a FARO arm was not considered for recording of YK 14's hull timbers due to the cost of the device and the potential difficulties involved if repairs in Turkey were required; Harpster (2005a, 61) came to the same conclusion during his study of the hull remains of the Bozburun shipwreck.
[236] The significant details to document on hull timbers are discussed in Steffy 1994, 191-213.

While the ship's frames and smaller hull planks could easily be handled by one or two individuals using wooden pallets, documenting the larger hull timbers presented greater logistical challenges. Large timbers on custom-built plank molds were too heavy to remove from the outdoor wet-storage tanks. In order to catalog these large timbers, the plank molds were removed from the timber crate and propped above the water level inside the storage tanks (**Figure 2.25**).

Figure 2.25: Timber cataloging at INA-BRC. The large planks and keel timbers were cataloged in outdoor water storage tanks (Photo by R. Ingram).

Even the largest timber boxes and molds, however, could usually be handled by one or two people while submerged in the timber storage tanks due to their buoyancy: both the crates themselves and the molds were built of pine wood that became negatively buoyant after several months to a year of submersion in wet storage tanks. Working in the storage tanks also made it easier to keep the wood wet, a requirement for avoiding drying damage to the timbers; at the end of the work day, the mold could be easily submerged in the water once again. The climate in Bodrum was generally conducive to this work arrangement; work in the timber storage tanks was practical between April or May to October or November. During the other months rain and the lower temperature of the water made work in the storage tanks more difficult, so a seasonal work schedule was adopted, where work on large timbers at the outdoor tanks proceeded in the summer and autumn, and work in the winter was conducted on smaller timbers inside the BRC's wood laboratory.

The documentation of two of YK 14's large keel timbers, Keel 2 and 3, also proceeded in the timber storage tanks. The 6.55-meter main keel timber, Keel 2, did not require a mold during its lifting and removal from the site, but due to the weight of the timber, the crate for the timber was built with a bottom heavily reinforced with 5 x 10 cm timbers. For the drawing and cataloging of this piece, the sides of the crate were unscrewed and the timber was propped with bricks in the timber tank on top of other large timber crates (**Figure 2.26**). Keel 3, although smaller, was in a heavily reinforced crate which could not easily be dismantled. This timber was cataloged on a reinforced 4-meter pallet built from marine plywood and 5 x 10 cm beams for the cataloging of keel timbers from the

Yenikapı ships at the BRC.[237] Keel 3 was moved while submerged onto the weighted pallet and kept on it for the duration of the cataloging process.

Figure 2.26: Keel 2, the main keel timber of YK 14, set up for photography of its inner face. The white photographic background material was inserted beneath the keel while it was still submerged in the holding tank.

Photography of the timbers was undertaken outdoors for all of YK 14's timbers due to the superiority of natural lighting in certain conditions for photography. Timbers were

[237] The marine plywood surface was selected because a flat surface was needed for taking cross sections of the keel timbers.

photographed on a white background consisting of a white oilcloth material called *muşamba* in Turkish. This material is durable and easily cleaned, and resists iron concretion and pitch stains fairly well; large pieces also served as improvised backdrops for timber photographs. For photographing large plank and keel timbers, lengths of *muşamba* were inserted beneath the edges of the timber; the surface of the 4-meter pallet built for handling large keel timbers was also covered in this material for a convenient background for photographs.[238]

A four-meter-long white linen sheet attached to a pair of PVC pipes was also used as a photographic backdrop, particularly for larger timbers; two lengths of reinforcement bar embedded in concrete bases were used to support the backdrop when necessary (**Figure 2.27**).[239] Timbers were kept wet while photographing, although it was found that the best results for photographing surface features were when the surfaces were only slightly wet: this greatly enhanced the visibility of surface details such as tool marks, but without the reflections caused by excessive water or the dull appearance of a drier timber surface.

[238] Inserting *muşamba* under timbers was often easier when the timber was still submerged in the water, as the waterlogged timbers are neutrally buoyant.

[239] The photographic set-up, conceived and assembled by Rebecca Ingram, consisted of two concrete bases with lengths of rebar embedded in them. A four-meter white sheet was sewn over so that its ends formed sleeves that fitted over two-meter-long PVC pipes, which were in turn inserted on the reinforcement bars. The sheet could be rolled or unrolled to the desired length (up to four meters), depending on the length of the piece being photographed.

Figure 2.27: Set-up for photographing the edge of a hull plank using plastic crates, a wooden pallet, and photography backdrop constructed from linen sheets, PVC pipes, and a pair of concrete-and-reinforcement-bar bases.

During the recording process, cleaning, sampling, and some of the preparations for the timbers' conservation with PEG were also begun. Since the plastic labels used during the excavation to label individual timbers were susceptible to damage by the PEG-treatment process, these were replaced with stainless steel labels. Additional labels were also added where necessary to avoid confusion in the reconstruction process; for example, labels denoting frame or other timber locations, or port- and starboard-side components. Timber-cleaning is also necessary prior to conservation. Although each timber was cleaned in a preliminary fashion upon excavation, further cleaning was carried out during the documentation process to remove iron concretion and pitch and sediment, which could potentially not only conceal details of the wood surfaces and locations of fasteners but also may complicate the conservation process.

The timbers themselves were sampled both for wood species identification by Nili Liphschitz of Tel Aviv University and, in several cases, for dendrochronological analysis by Tomasz Wazny and Brita Lorentzen of the Aegean Dendrochronology Project at the University of Arizona. Organic remains such as caulking in plank seams and waterproofing materials applied to the timbers' surfaces were well preserved on the majority of timbers. Most of these remains were removed, and caulking and pitch were sampled extensively for later identification and analysis (see Chapter VI). The pitch coating on the timbers frequently completely covers the surfaces of the wood so that features such as tool marks and builder's guide marks are often extremely well preserved; for these reasons, it was necessary to remove much of the pitch for the drawing and cataloging the timbers, especially on the hull planking. However, because the timbers' surfaces are often quite soft, the pitch needed to be removed very carefully. The best method for this is to carefully flake or scrape away the pitch with a scalpel or dental pick. In the case of more degraded pitch, gently rubbing the surface while washing it with a stream of water can also be effective, although more vigorous scrubbing of the wood surfaces can obliterate surface detail; sand and shell debris are frequently embedded in the pitch and can act as an abrasive when rubbed against the timbers' surfaces. Careful cleaning of the timbers is necessary from the standpoint of conservation of material as well as documentation. Pitch on the hull planks and caulking in the plank seams sometimes preserved (and concealed) important information on how the ship was used; timber cataloging frequently requires recording information on the timbers both before and after the removal of this material. Details on the original surfaces of the timbers, which may need to be examined in the future, are also more difficult to distinguish after conservation if they are conserved while still covered in pitch.

After the initial documentation of the hull timbers and other remains were completed, the process of reconstructing the ship was begun. The information collected during the cataloging process and the reconstruction of the ship is presented in Chapters III and IV. Chapter V details a proposed reconstruction of the ship's rig based on YK 14's hull remains and other sources of evidence on medieval Mediterranean ship rigs. Chapters VI-VIII present interpretations of the hull remains based on the materials used in the ship's construction, comparison of YK 14 to other shipwrecks from the Yenikapı site and elsewhere in the Mediterranean, and general conclusions on the role of the vessel in Byzantine maritime trade and technology.

CHAPTER III

CATALOG OF HULL TIMBERS AND HULL CONSTRUCTION FEATURES

The documentation of YK 14's hull remains includes 1:1-scale drawings, timber catalogs, photographs, and reconstruction drawings and models. This chapter consists of a summary of the features of the hull timbers based on these records, beginning with a general description of the hull remains of YK 14 as they were found, followed by a description of some general characteristics of the hull timbers and hull construction methods used in the ship, including tool marks and fasteners, and concluding with the catalogs of specific timber types (keel timbers, planking, frames, etc.) and, where necessary, individual hull timbers.

1). Introduction: Overview of the Hull Remains, Surface Features and Production Methods, and Hull Fasteners[240]

Overview of the Hull Remains

The remains of Yenikapı 14's hull were approximately 11.73 m long and 2.55 m wide at their widest preserved point, near amidships at floors FL 28-30. Approximately one-third of the hull was preserved. The vessel had settled on the seabed listing towards its starboard side, was which preserved up to the area of the waterline, while the port side

[240] Refer to the Glossary of Nautical Terms (Appendix B) for definitions of terms not defined in the text of this chapter.

was preserved to the area of the turn of the bilge. A total of 128 timbers were preserved in the main hull section (**Figures 3.1-10**), which included the following components:

1) An intact central keel timber, Keel 2, was preserved with two shorter, intact curved keel timbers (Keel 1 and 3) attached to its ends with keyed-hook scarfs. Aside from a small remnant of an endpost found in the aft scarf end of Keel 1, the smaller of the two curved keel timbers, no traces of the endposts survive. Five scarf keys from the keel scarf joints survived, four of which were found in situ in the keel scarfs. The scarfed ends preserved on the keel timbers at either end of the ship joined the stem and the sternpost; these were most likely shaped from single timbers.
2) Sixty-five hull planks survived in the main section of the ship, comprising seven strakes on the port side (SS 1-7) and eighteen strakes on the starboard side (PS 1-14, PS 5A, PS 10A, 10B, PS 12A).[241] A single wale, PS 13, was preserved on the starboard side. Strakes PS 1-3, PS 5, PS 5A, SS 1-3, and SS 5 are complete, while all the strakes above them are incomplete, with either missing planks or have planks with broken ends.

[241] During the excavation of YK 14 in 2007, one end of the hull was designated the 'bow' for labeling purposes, since the hull was double-ended and no clear evidence of its original bow and stern survived. As a result, planking on the better-preserved side of the ship was labeled with 'PS' (Port Strake) designations while planking on the starboard side was labeled with 'SS' (Starboard Strake) designations. Subsequent analysis indicates that the 'stern' from 2007 is actually the bow, for reasons explained in the keel and planking catalog sections in this chapter and summarized in Chapter IV. The bow end is of the hull is at FL 51 and the end of Keel 3, while the stern is at FL 1 and the end of Keel 1; 'port' and 'starboard' are cited accordingly, with the 'PS' labeled planks on the starboard side and the 'SS' labeled planks on the port side. No midship frame was designated during the excavation because only the general midship area, consisting of approximately six floor timbers (FL 24-30), could be identified.

3) Sixty-two frames, including 45 floor timbers and 17 starboard futtocks, were found either attached to the surviving hull or recovered loose in the excavation area and subsequently matched to their original locations in the ship. Evidence for 5-7 additional floor timbers or possible floor timbers,[242] as well as additional futtock and top timbers, were preserved on the keel and planking timbers in the form of fastener holes, frame edge impressions, and features of the pitched areas of the hull planking (e.g., pitch 'ridges' at the original locations of frame edges, etc.).

4) One stringer, ST-1, was fastened to several starboard futtocks inside the hull and ran parallel with PS 14, the highest preserved strake on the ship. On the inner faces of the floor timbers, fastener holes and pressure marks indicate the possible locations of additional internal timbers such as stringers and ceiling planking, but the evidence is ambiguous.

[242] These include FL 1-3 in the stern (although "FL 1's" fasteners may be hood end fasteners on PS 3-1 and SS 3-1 rather than frame fasteners) and FL 49-51 in the bow. Evidence for FR 52 consists of a fastener hole in the forward, broken end of PS 6-3, but this fastener could be for a floor, half-frame, futtock, or hood end.

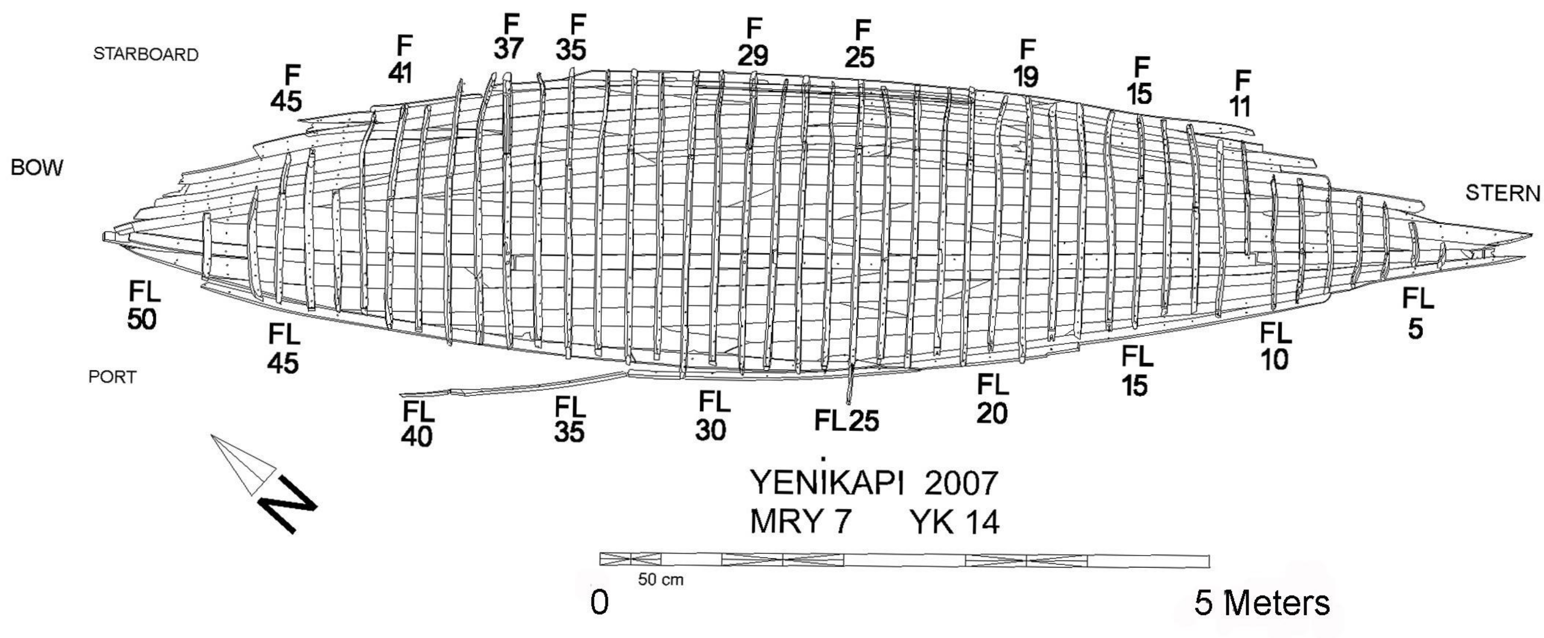

Figure 3.1: YK 14 total station plan with selected frame positions and stringer labeled.

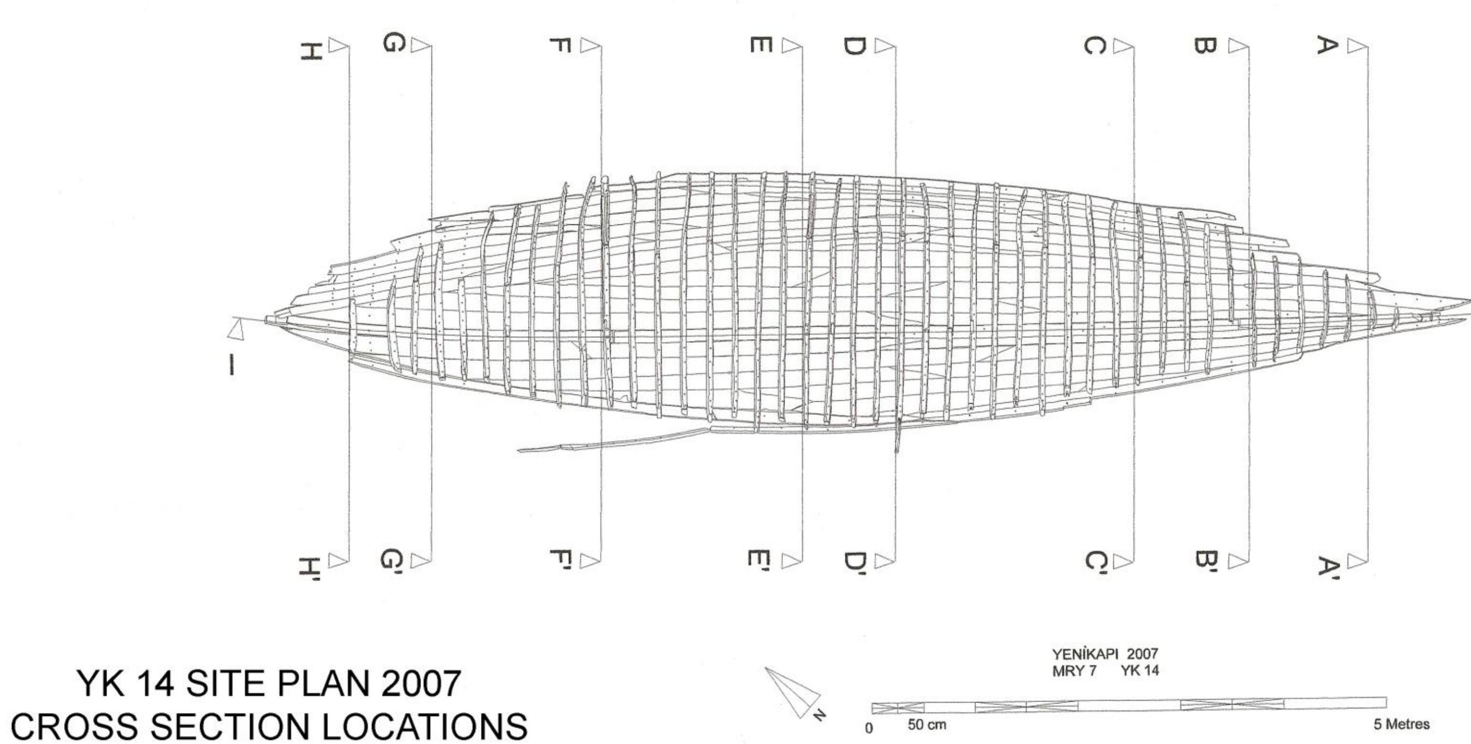

Figure 3.2: YK 14 total station plan showing locations of cross section (Plan and sections by S. Matthews).

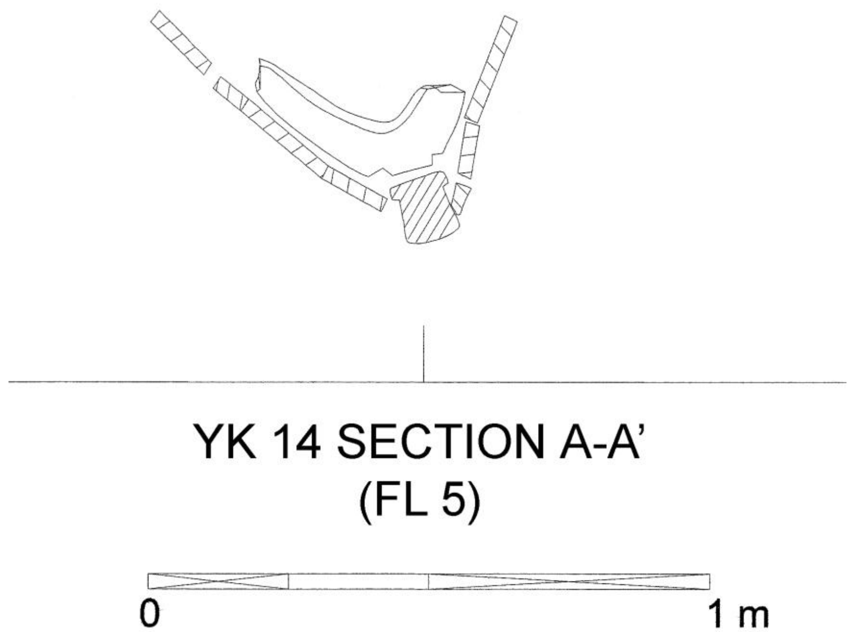

Figure 3.3: Cross section of hull at FL 5.

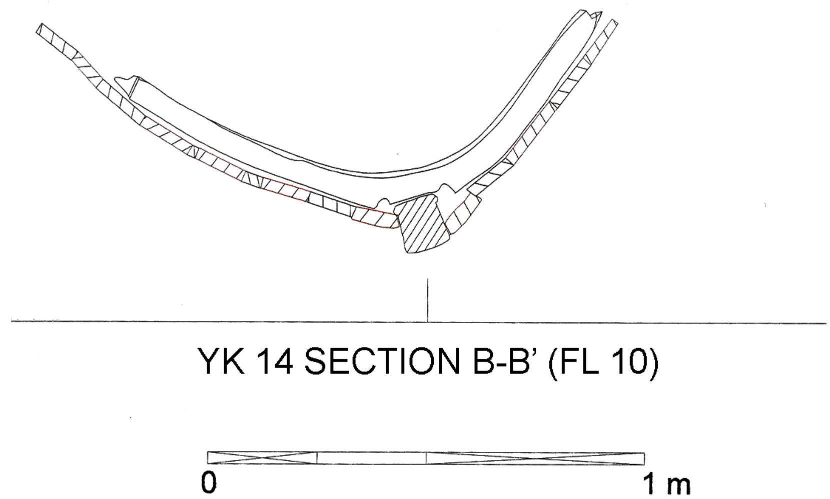

Figure 3.4: Cross section of hull at FL 10.

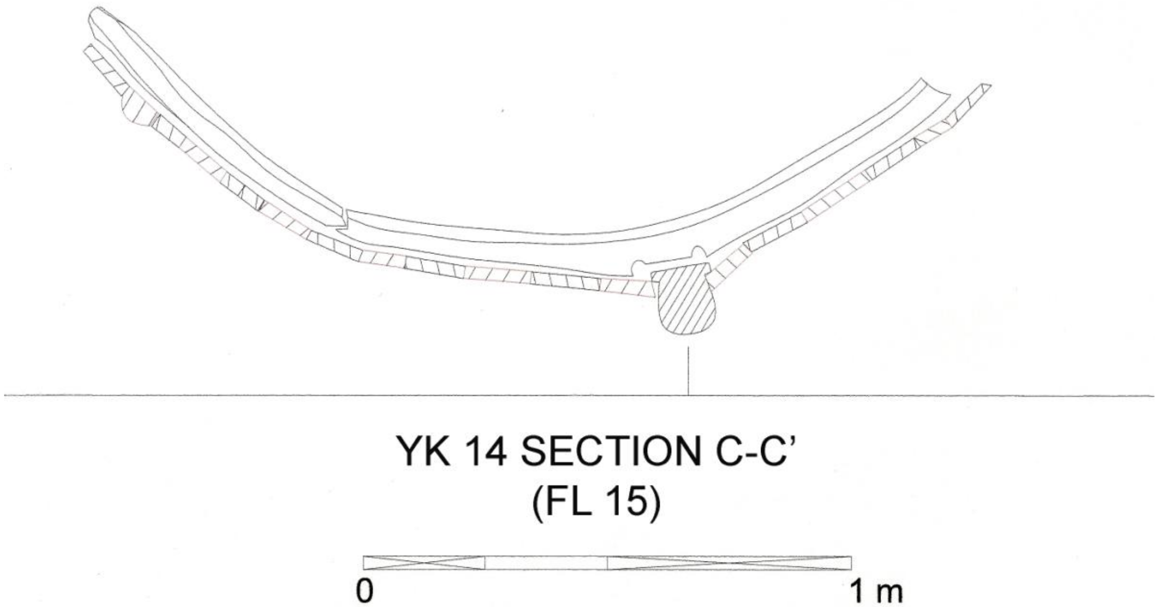

Figure 3.5: Cross section of hull at FL 15.

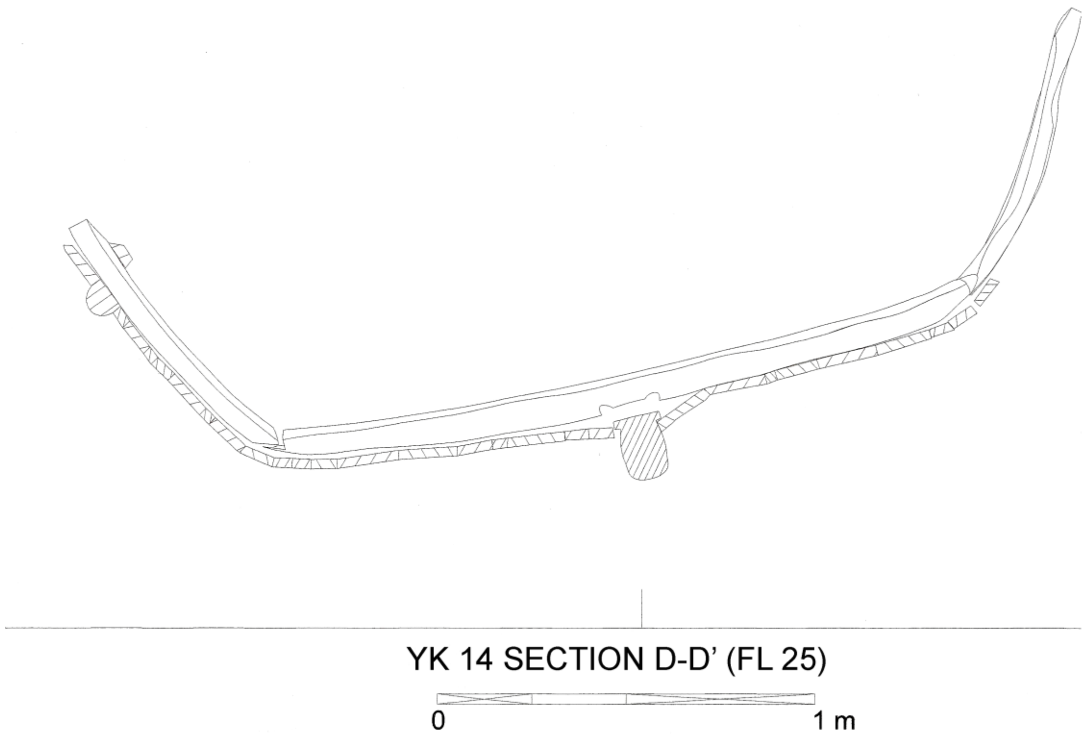

Figure 3.6: Cross section of hull at FL 25.

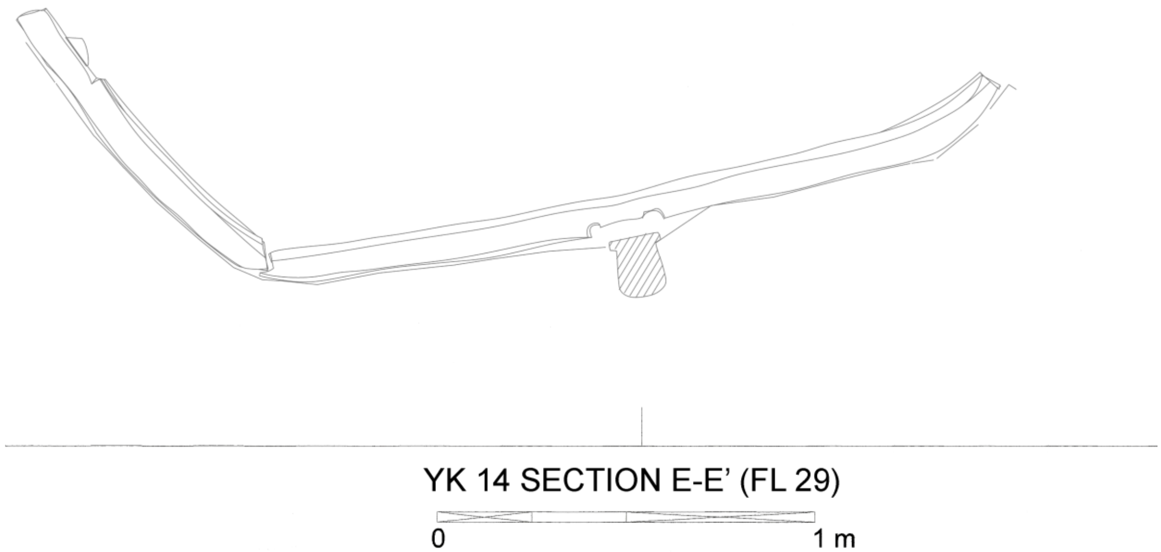

Figure 3.7: Cross section of hull at FL 29.

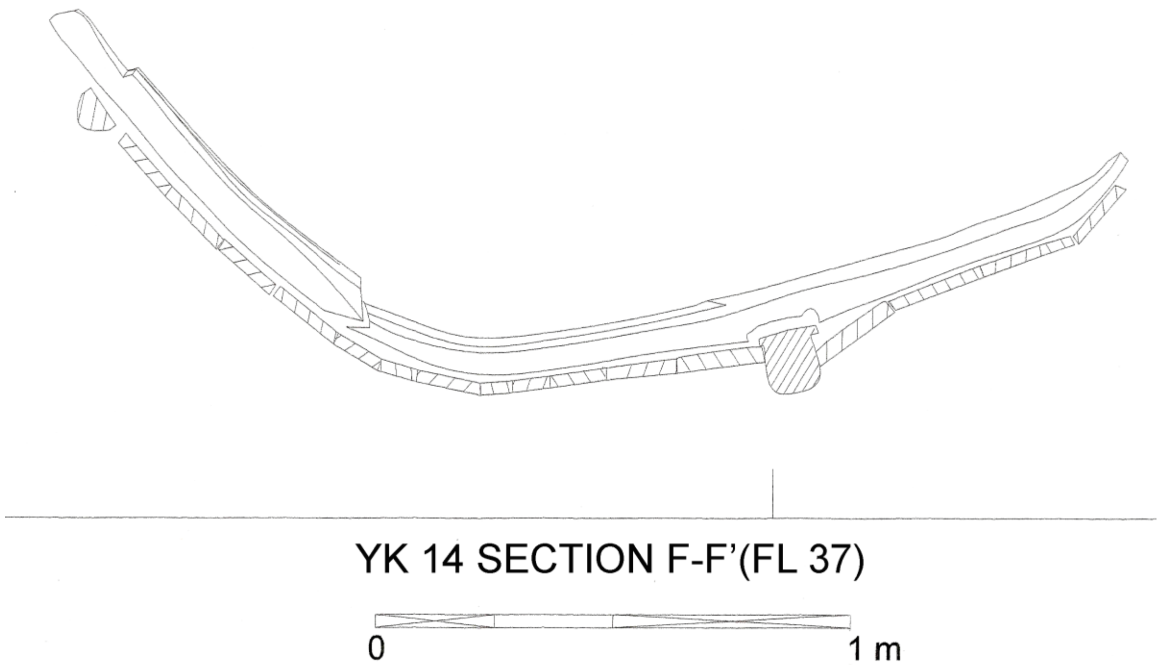

Figure 3.8: Cross section of hull at FL 37.

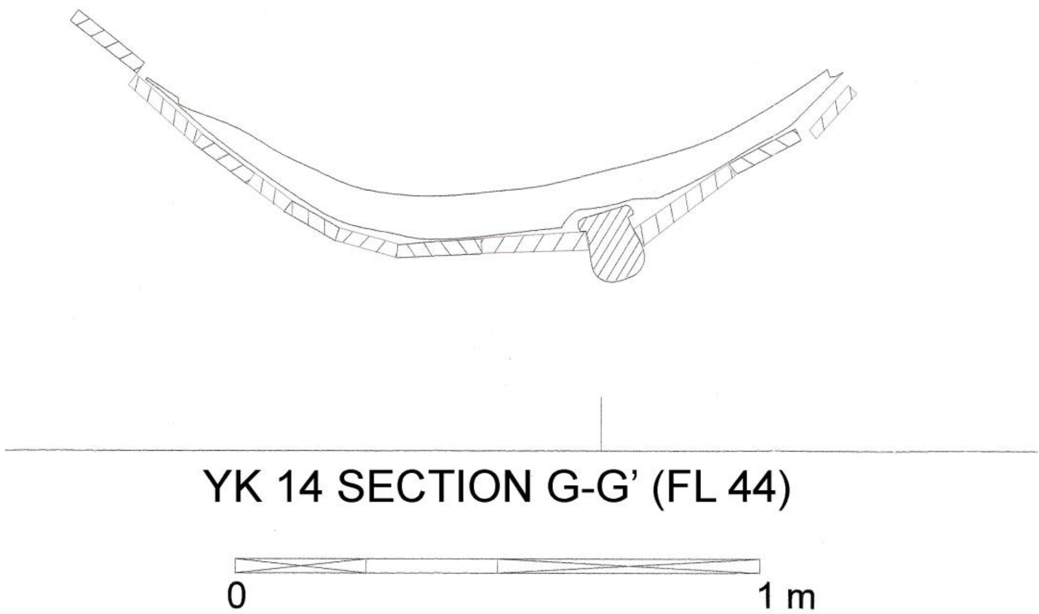

Figure 3.9: Cross section of hull at FL 44.

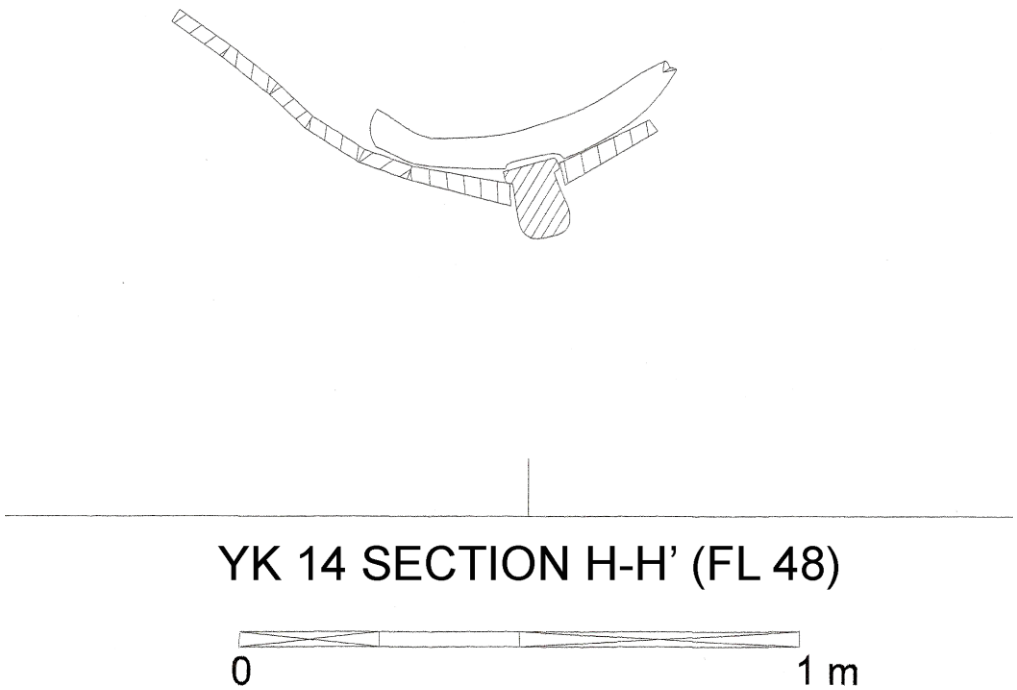

Figure 3.10: Cross section of hull at FL 48.

Additionally, 24 disarticulated fragments from unidentified members (UM) fragments, representing 22 separate timbers, timber fragments, and rigging elements were discovered around and under the hull; many of these timbers are likely parts of the missing sections of the starboard side of the hull or upper section of the ship.[243] The original locations of three of these timbers in YK 14 were later identified, including one

[243] The unidentified members were designated by a 'UM' label followed by a number, based on the order in which they were discovered (from 1-24), aside from the possible rigging elements, which were numbered later. The terminology for 'UM' or 'Unidentified Member' timbers is taken from the Serçe Limanı hull study (Bass et al. 2004, 77-8; see also Steffy 1994, 195).

floor timber (FL 47, formerly UM 16), which was torn from the hull during the sinking of the ship, and UM 10 and 11, which joined a broken end of floor FL 27. Fragments UM 3 and 6, which were originally parts of the same frame timber, were also found to join. In 12 other cases, the UM timbers could be identified as specific types of ship timbers, and their general locations in the hull of YK 14 (or another vessel) ascertained. Of the remaining 19 UM timbers recovered, eight are very likely to have come from YK 14 based on similarities to certain types of hull timbers from the ship. Six others are clearly ship timbers, some or all of which may have come from YK 14, while the remaining four UM timbers have no clear characteristics of ship timbers, and could have been scrap wood carried on board or simply debris from the harbor.

Some distortion of the ship's hull occurred during and after the ship's sinking. Planking sprung outward from broken sections of the hull above the turn of the bilge, particularly SS 7-2 on the port side and the strakes above PS 10 on the starboard side between frames 31-46. The hull is slightly hogged, probably due to a combination of distortion that occurred during the life of the ship and compression of the hull occurring after the ship's sinking and deposition in the harbor. Most of the floor timbers in the central section of the hull had pulled away from the keel, probably during the wrecking of the ship. This resulted in cracks and breaks in several floor timbers where they overlap the keel, particularly at the locations of nails used to fasten the floors to the keel (**Figure 3.11**). The floors were separated from the keel at FL 4-5, 16-35, and, to a lesser extent FL 39-46, with those between FL 21-35, or approximately amidships, pulled furthest away from the keel's inner face. The formation of iron concretions on the outer faces of the keel nails at FL 26, 30, and 32 preserved the approximate width of the gap between the outer face of these floor timbers and the inner face of the keel: the gap ranged from a few millimeters (FL 16-20, FL 39-46), to several centimeters along the main keel timber, Keel 2 (FL 21-35). While the main keel timber appears to have remained relatively straight, some bending or distortion is evident at both scarf ends of the timber.

Figure 3.11: View of the keel area amidships during excavation, with FL 22 in the foreground. Note the breaks on floors FL 23-24 where they overlap the keel, and the separation of FL 25-28 from the keel.

Post-sinking shipworm or teredo worm damage was seen on several timbers only in the uppermost section of the hull, including planks PS 9-1, PS 14-1, and SS 6-1, and in the upper ends of frames FL 7, F 11, F 13, F 17, and possibly FL 4 (**Figure 3.12**). The largest of the teredo worm holes were 0.8-1.2 cm in diameter, but most are only 0.4-0.5 cm in diameter. These holes were usually scattered in the upper extremity of the hull, and their absence elsewhere indicates a relatively short period of exposure to marine borers. Knot holes and cavities caused by boring insects and wood rot were present in several timbers. In some cases holes in the hull planks were plugged with caulking and pitch: these include a knot hole in plank SS 4-2 (**Figure 3.13**) and a boring left by beetle larvae in plank SS 5-2.[244] A possible insect hole, which was not plugged due to its presence in the interior of the hull, was also found in floor FL 29. Wood rot, which caused some of the most serious damage in the hull, occurred before the ship's sinking on many frame and planking timbers as well.

[244] A caulked hole in hull plank SS 2-2, at the location of frame FL 26 and measuring 0.9 x 0.7 cm could be an insect hole, but is more likely a plugged nail hole. Larvae from three separate families of beetles (from the order Coleoptera) leave such burrows in oaks (C. Pulak, personal communication).

Figure 3.12: Teredo worm damage on the upper end of futtock F 17, one of the few timbers in YK 14's hull to exhibit such damage.

Figure 3.13: Knot hole in plank SS 4-2 repaired with a plug of pitch, hair, and grass. Note the hair in the plug, which had been partially removed when the photograph was taken.

The formation of iron corrosion from clusters of iron nails in the wood caused splitting and breaks in a few frames amidships, most seriously in floor FL 24. However, the hull's original shape appears to be well preserved overall, with little or no distortion to the frames. The frames of the ship generally seem to have broken when under excessive stress rather than becoming distorted.

A number of features were common to several categories of timbers, including marks from tools used during construction, protective surface treatment of the timbers, and the fastener types used. Those characteristics that are common to all or to a large number of the timbers of the ship are described first, while more unusual or unique features are discussed in later sections of the chapter on specific timber types and individual timbers. The catalog has been arranged according to timber type, based roughly on the order in which they were installed during the construction of the hull (i.e., keel, planking, frames).

2) Tools Used in Construction, Ship's Fasteners and Fastener Holes, and Other Surface Features of the Hull Timbers

Pitch

Due to the rapid burial of the hull and the protective pitch coating on many of the timbers, surface features on the ship's timbers are generally very well preserved and offer a great deal of information on the vessel's construction and use. The pitch coating survived on much of the inner and outer surfaces of the hull. Inside the hull, the degree of pitch preservation varied, but the deposits were generally 0.1-0.2 cm thick. Thicker pitch ridges occurred at the edges of frames and in the indentation between the keel and garboard-strake seam, where the garboard was fastened into the rabbet in the keel timbers. Very little pitch survived on the exposed inner faces of many of the frame timbers, although it was better preserved on the forward and aft faces of these timbers. On most surfaces, the pitch had weathered so that it was no longer hard or sticky, and could be readily flaked off the surface of the timbers. Sand and pebbles, organic debris such as twigs and wood fragments, leaves (possibly from dunnage?), seeds (particularly of grape, but also olive and cherry pits), and fragments of chestnut skins were common inclusions in the pitch. Hair inclusions found in well-preserved pitch deposits on many timbers had been mixed with the pitch to increase its adhesive qualities; grass stems similar to those used in caulking the seams were also frequently found embedded in the material. Pitch was found under some, but not all, of the frames in the hull; in some cases damage from rot was partially pitched over This suggests that pitch leaked under some of the frames over time or was deliberately applied when leakage and rot occurred under the floors. It is unclear whether pitch was applied to the outer faces of the floors during construction; no clear pitch deposits were found on the floors' outer faces other than occasional deposits at plank seam locations, but any pitch applied to these surfaces during construction could have been washed away over time.

The pitch coating on the outer face of the planking was frequently thicker—often 0.5-1 cm in thickness or more—than that found in the interior of the hull.[245] The coating was at its thickest on the port and starboard faces of the keel timbers, the keel/garboard plank seams, and the seams around PS 13, the only surviving wale in the hull. The pitch on the outer face was full of inclusions from harbor sediments, and appears to have worn off in some areas that may have been frequently exposed to wear. The pitch coating on both outside and, less often, inside the hull must have been periodically renewed during the lifetime of the ship; occasionally, two separate layers of pitch of different colors and consistencies could be discerned on the hull planks.

Over the course of the excavation, pitch in some of the more exposed parts of the hull was washed away by the frequent exposure to water from hoses and the sprinkler system used in keeping the hull wet. The greatest effect of this exposure was seen on the inner faces of frames and hull planking above the turn of the bilge and in the lowest portion of the wreck where water tended to collect. The timbers most representative of the original pitch coating on the inside of the hull were located below the turn of the bilge at the stern, particularly planks PS 1-1 to PS 3-1 and SS 1-1 to SS 3-1.

[245] Due to the size and shape of many of the hull planks, it was not possible to systematically examine the outer faces of every plank. These statements are based on the examination of the outer faces of the smaller hull planks as well as broken pieces from some of the larger planks that were not recovered intact. The outer faces of these planks and plank sections were also photographed.

Tool Marks and Tools Used in the Construction of the Hull

Tool marks from several types of tools are preserved on the surfaces of the hull timbers. The use of other tools may be inferred from the design and construction of the vessel and from knowledge of woodworking and shipbuilding technology of the period. This section is mainly concerned with the tools and methods used in shaping timbers for use in the hull; the possible methods used for determining the hull's size and shape, and the construction sequence of the ship will be discussed in detail in Chapter IV.

The timbers used to construct the ship were felled with axes, probably very similar to the felling axes discovered on the early eleventh-century Serçe Limanı shipwreck, the tenth-century Agay A 'Saracen' shipwreck, and the tenth-century Yenikapı shipwreck YK 5.[246] Similar axes are also portrayed in Byzantine manuscripts, particularly those of Hesiod's *Works and Days*, which are often illustrated with contemporary tools used by farmers.[247] Tool marks from this initial felling were almost certainly removed during the later shaping of the timbers, although one deep, 9.0 cm-wide cut mark observed on the outer face of plank PS 2-2 could have been made with an axe or a large adze during felling or the early stages of shaping the timber.

At least two types of saws, along with a possible third type, were employed during construction, primarily in the initial cutting and shaping of planks and frame timbers.

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[246] Hocker 2004a, 315-7, Fig. 18, no. T 34; see also Ximenes 1976, 147, Pl. IV, 2 and Fig. 15. An axe head concretion nearly identical in shape to axe T 34 from the Serçe Limanı wreck was found in the hold of the YK 5.
[247] Bryer 1986, 57-8, 61-2, 64, 69, 71, 73.

Saw marks on the hull timbers offer some clues as to what types of saws were used. For the larger planks, a large frame saw or pit saw with coarse teeth would have been used to cut (or 'rip') logs into planks. These were typically used by two sawyers, one above and one below the log being cut, with the lower man either in a pit or the upper man on the log standing on a trestle upon which one end of the log was propped. In later shipbuilding traditions, sawyers of this type were itinerant, working on short-term contracts during the first stages of a vessel's construction.[248] Roman and medieval artists frequently depicted the use of these saws, which have also been used in some parts of the world into modern times.[249] Saw marks frequently occurred on the inner faces of YK 14's hull planking; these are usually slightly angled to the length of the planks, and most have a seemingly uniform, wide spacing of 0.3-0.9 cm, unless they are near a knot or some other harder area in the timber, in which case the marks are more closely spaced or occur at different angles. On a few timbers, such as the garboard planks SS 1-2 and SS 1-3, the saw marks are angled in several directions (**Figure 3.14**). Although many of the outer face surfaces of the hull planking were not examined due to their size, and fragility, occasionally saw and adze marks were also found on the outer faces of those planks that were examined. In most cases, however, the planks' surfaces were either too worn or damaged by impressions of shells, stones, and other debris to retain well-preserved tool marks, or were obscured by thick layers of pitch. Either a smaller frame or bow saw or a hand saw was likely used to cross-cut planks to the desired length and

[248] Greenhill 1971, 74-80, 104.
[249] Hocker 2004a, 310; see also Goodman 1964, 119, 134-39; Rival 1991, 136, Pl. 21; Unger 1991, Fig. 3, 7, 20, 44-6, 48, 50, 55-7, 59, 63; Meiggs 1998, 348-49; Ulrich 2007, 45, 48.

for the initial shaping of frame timbers; most of the floors have sawn ‘flat’ faces, resulting from sawing the curved timbers longitudinally.[250]

Figure 3.14: Saw marks on SS 1-3 angled in multiple directions. Note also the adzed area towards the lower edge of the plank.

[250] See Bryer (1986, 65), Unger (1991, Fig. 47, 62, 70, 74), and Ulrich (2007, 35, Fig. 3.23; 49-50, Fig. 3.38-9) for some Roman- to Renaissance-period representations of crosscut or bow saws and hand saws. Most archaeological evidence of saws from Roman-period sites consists of small fragments of saw blades, but several more or less complete examples have also been found (Goodman 1964, 116-22; Manning 1985, 19, 21, Pl. 9, n. B21-3; Ulrich 2007, 47, 51, 347-48). Two intact frame saws were discovered on de Meern 1, a late-second-century C.E. Roman barge found west of Utrecht on a tributary of the Rhine (Van Holk 2006, 296, 298, Fig. 48.8-9). This vessel included a pair of adzes and three complete planes, also intact; this set of tools probably belonged to a carpenter involved with the Roman military on the empire’s frontier (Van Holk 2006, 298, Fig. 48.7, 48.10).

A small handsaw may have been used to cut diagonal scarfs on planking, scarf ends on frames and keel timbers, and for other jobs requiring more precision. Examination of the tree rings at ends and breaks of hull planks indicate that they were plain sawn from logs of relatively small-diameters (**Figure 3.15**).[251] The use of smaller saws seem to be indicated by saw cuts on smaller-sized timbers, more closely-spaced saw marks (often only 0.1-0.5 cm apart, which was common on the sawn faces of curved sections of floor timbers), or saw marks that show more variety in orientation on a particular face of a timber.

Figure 3.15: Example of clearly visible wood grain and tree rings at a break in plank PS 2-2, between frames FL 24 and 25.

The hull timbers were shaped largely with adzes.[252] Adze marks with widths of up to 4-6 cm wide were measured on the surfaces of the frames, keel timbers, and planking.[253] In

[251] The oak timbers used in the construction of YK 1 and 5 as well as YK 14 were relatively small in diameter (Liphschitz and Pulak 2009, 170-71). See Chapter VI for a more detailed discussion of the timber used in the construction of the ship.
M. Katzev states that “The adze was the preeminent tool of the shipwright. With it he could strip surplus material from logs and roughly shape a keel, a plank, or a frame; he could level edges to yield flush joints, trim flat and curved faces to obtain tight fits and finish surfaces smoothly. It was this tool he would use

some cases, nicks in the blade of an adze left striations within the tool mark that indicated the direction of the cut, and cut marks from specific tools can be identified in some areas of certain timbers (**Figure 3.16**). Clear adze marks were observed in many areas on the inner faces of the hull planks, on all faces of the keel timbers except for their outer faces—which were badly worn on all three keel timbers—and on at least three of the four faces of most frame timbers. Archaeological examples of adzes from Byzantine shipwrecks and Roman- and Byzantine-period archaeological sites have blade widths ranging from 7.2 to 15.7 cm; adzes of these sizes, particularly those with blade widths of 7-9 cm, could have easily made the tool marks found on the YK 14 timbers.[254]

most in building a ship, and, similarly, it was this tool that the Byzantine ship's carpenter would have found so versatile for making repairs" (Katzev 1982, 242). See Petrie (1917, 18, Pl. XVIII), Katzev (1982, 242), and Ulrich (2007, 16-8), for an original example and reconstructions of slot-adzes.

[253] Mor (2003, 166) and Bass et al. (2004, 111) note adze marks of similar sizes on the timbers of the Ma'agan Mikhael ship (late fifth century B.C.E.) and on the Serçe Limanı ship (c. 1025 C.E.). Ward observed adze marks in this size range on the Dashur boats in Cairo and Chicago as well (Ward 2000, 28).

[254] Five adze concretions were recovered from the seventh-century Yassıada wreck (Fe 14-8), with blade widths ranging from 7.2 to 8.3 cm; Fe 15, with a maximum blade width of 7.9 cm, was found with other tools suggesting that they were a single set belonging to the ship's carpenter (Katzev 1982, 240-42, 265). Cast concretions of adzes from the Serçe Limanı shipwreck had wider blades, ranging in width from 6.3 cm (a damaged example) to 15 cm (Hocker 2004a, 298-301). Archaeological examples of Roman adzes and adze-hammers have blade widths ranging from 8.0 to 15.7 cm (Ulrich 2007, 337; see also Manning 1985, 16-8, Pl. 8-9). Hocker has suggested that the widths of adze blades from the Serçe Limanı ship may have been designed with narrow, medium-width, and wide blades, perhaps roughly corresponding to multiples of the Byzantine 'finger' or *dactyl*, which is approximately 1.95 cm (Schilbach 1970, 16; see also Hocker 2004a, 300-1, 322, n. 23).

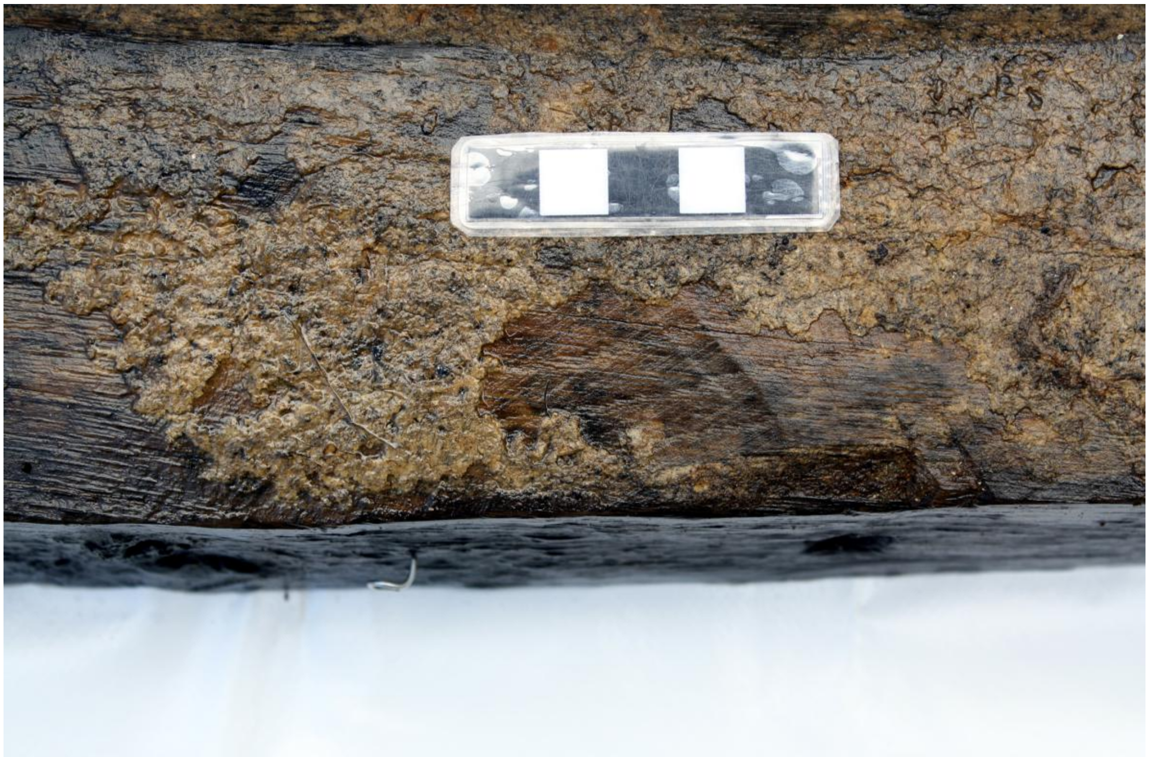

Figure 3.16: Example of a well preserved adze mark on futtock F 37 with striations from irregularities or notches in the blade.

Chisels and gouges were used for cutting mortises in the floor timbers for stanchions and the mast step, the shaping of the keyed-hook scarfs on the keel timbers, the cutting of limber holes, grooves for bulkheads in frames, and likely the triangular chamfered cuts for countersinking the heads of nails used to fasten floor timbers to the keel.[255] The carpenters probably owned several types of chisels of varying sizes and shapes for different tasks; such variety is standard in modern carpentry tool sets and is also reflected by archaeological finds of Roman and Byzantine carpentry tools. Six chisels

[255] Some tool cuts, such as countersunk notches for nail heads, could have been made with the corner of an adze blade or by striking the blunt end of an adze head with a hammer. It is not always possible to distinguish the difference between adze and chisel marks, especially when wide-bladed chisels are used (C. Pulak, personal communication).

with blade widths ranging from 2.0 to 4.3 cm were included among the carpentry tools on the seventh-century Yassıada shipwreck,[256] while five chisels with minimum blade widths of 0.8-1.7 cm were found on the Serçe Limanı ship.[257] Based on the widths of chisel marks left in the wood, the chisels used during the construction of YK 14 probably had blades at least 1.2-3 cm wide, similar to the blade widths of other Roman and Byzantine examples. Some of the clearest chisel marks on a frame, those in the groove cut into the inner face of F 37 for a bulkhead, are approximately 1.2 cm wide (**Figure 3.17**).

Figure 3.17: Tool marks from a chisel used in cutting a groove in the inner face of futtock F 37 for bulkhead planks.

[256] Two of the chisels were recovered without their cutting blades preserved; one, Fe 24, was 1.5 cm in diameter (Katzev 1982, 246).
[257] Katzev 1982, 246; see also Hocker 2004a, 304-5. For other examples of Roman chisels and gouges, see Manning 1985, 20-5, Pl. 10-1; Goodman 1964, 196-97; Ulrich 2007, 26-30, 340-41.

Drilled holes were common features associated with fasteners on all of the timbers. Holes were drilled for treenails using one or more drill bits of approximately 1.2-1.5 cm in diameter.[258] Several drums for bow drills were discovered at Yenikapı; they are likely very similar to the ones used in the construction of YK 14.[259] Most drilled holes were made for coaks to fasten hull planks to the keel and to each other, and for treenails used to secure planking to the frames. These holes would have been slightly smaller than the diameter of the wooden fastener shaped to be driven into them.[260]

Significant numbers of drilled holes served as pilot holes for nails (**Figure 3.18**). These would have been made to avoid splitting of the wood, which could cause leaks and weaken the connection between timbers, as well as to keep the nail following its intended path rather than the wood grain.[261] Pilot holes for nails can be of a smaller diameter than that of the nail itself, since the nail's holding strength derives from friction between the nail shaft and wood. One consequence of this is that some pilot holes may no longer be evident, having been obliterated when the nails were driven. Some of the smaller drill bits found on the Serçe Limanı wreck, with diameters of 0.7-0.8 cm, could

[258] On the seventh-century Yassıada ship, three drill bits were found: two with tapered points of 0.6 cm in diameter, which could have been used for drilling pilot holes, and one that would have drilled holes approximately 1.4 cm in diameter, similar in size to drilled holes in the hull timbers of YK 14 (Katzev 1982, 249-51). For Roman-period examples of drill bits and augers, see Manning 1985, 25-8, Pl. 11-2.
[259] Two bow-drill drums from the Yenikapı site have been published, one with the concreted iron drill bit still in place (Çölmekçi 2007, 239-40, 303; see also Gökçay 2010, 145). A Roman period bow drill was found at Hawara in Egypt, and similar drills are shown in use in various Roman-period iconography (Ulrich 2007, 30-6, 342-43). Older archaeological examples from shipwrecks include three to four bow drills from the Ma'agan Mikhael shipwreck, and a single bow drill on the fourth-century B.C.E. Kyrenia ship (Udell 2003, 206-9; see also Hocker 2004a, 303, 322, n. 27).
[260] Hocker 2004a, 303; see also McCarthy 2005, 67.
[261] Hocker 2004a, 303. The drilling of pilot holes to avoid splitting the wood is standard practice in modern wooden shipbuilding in the Persian Gulf and the western world today (Agius 2002, 141; see also McCarthy 2005, 49, 61).

have been used for drilling pilot holes in the ship's hull.[262] However, larger pilot holes for nails were also drilled for some applications. The pilot holes for nails fastening many of the floor timbers to the keel were made with a drill bit of 1.2 to 1.5 cm in diameter, similar in size to that used for drilling treenail and coak holes.[263]

Figure 3.18: Drilled pilot holes for nails in the garboard strake near the aft end of SS 1-1/1A-5. Note the faint nail-head impression in the pitch around the drilled hole to the right**.**

This size of drill bit was also used for pilot holes for nails fastening the hood ends of planks to the keel and endposts, as well as in locations where nails were used to fasten planking to frames, and floor timbers to the keel. In the case of fastening planking to

[262] Hocker 2004a, 301-3.
[263] This was also the case on YK 1, 5, 11, and 24 recorded by INA at Yenikapı. Steffy notes that many of the planking nails used on the Serçe Limanı ship were also driven into pilot holes (Bass et al. 2004, 98). The use of a large-diameter drill bit for drilling many of the pilot holes in YK 14's hull may indicate that either a smaller-diameter drill bit was unavailable, or that the carpenter had a single bow drill and did not want to change drill bits frequently.

frames, the pilot holes were often shallow 'dimples' on the outer face of the plank and did not fully penetrate it. With repair planks fastened with nails, however, the pilot holes were typically drilled through the entire thickness of the plank and sometimes several centimeters into the frame as well. Again, these were probably drilled to prevent the plank from splitting, and the choice of a larger drill bit could have been determined by what tools were available for the repair rather than what was most suitable for the purpose. Shallow 'dimples' or drilled holes, about 0.5 cm in depth, are found at some locations in the inner faces of the hull planks and keel timbers as well. Although it is possible these had some sort of marking function, they appear to be in no discernible pattern. Often a drilled hole for a treenail is found near these 'dimples,' indicating that they are most likely abandoned drilled holes for fasteners.

In addition to saws, adzes, and at least one bow drill, several other tools were probably used during the construction of the hull. Hammers similar to the four examples found on the seventh-century Yassıada ship (as well as a hammer-adze) would have been necessary for driving nails and for work with chisels.[264] Mallets (or 'beetles') similar to example found at Yenikapı and on the Serçe Limanı and other shipwrecks would have been used to pound coaks and treenails in place during the construction of the hull, or to caulk or re-caulk plank seams with a caulking iron.[265] A sharp tool such as a knife was used to score the hull planking to mark the locations of frames and edge fasteners. The

[264] Katzev 1982, 242-46; see also Manning 1985, 17-8, Pl. 9; Ulrich 2007, 344.
[265] Gökçay 2010, 144; see also Hocker 2004a, 306; Ulrich 2007, 51, 344. Mallets were also found on the Ma'agan Mikhael shipwreck (late fifth century B.C.E.; Udell 2003, 209-10), on the Comacchio wreck (late first century B.C.E.; Berti 1990, 281, 284-88), and on the Blackfriars ship (mid-second century C.E.; Marsden 1994, 80-1).

wooden coaks and treenails used as hull fasteners were probably also whittled with knives, although a drawknife could have also been used to shape the treenails; this was the standard method of shaping treenails in later periods, and the tool was in use in the first century C.E. as indicated by a drawknife found at Pompeii.[266] Based on tool marks, edge chamfering and smoothing on the frames, plank edges, and other areas appear to have been done almost entirely with adzes. A block plane could have been used instead of an adze for this type of work, although according to Hocker "The plane is perhaps the least likely [tool] to have been included" among the Serçe Limanı ship's carpentry tools, since an adze serves the same function: planes rarely appear in medieval depictions of shipbuilding, although it was a common shipbuilder's tool in later periods.[267] No clear tool marks from a plane were found, although in some areas such as plank edges they would be difficult to detect if they were present. Clamps of some kind were probably also necessary during the construction of the hull, especially in aligning and edge-fastening the hull planking. Evidence for clamps from the Roman and Byzantine periods is scarce, but simple wooden clamps, which would generally leave no trace in the archaeological record, could have easily been used.[268] Props or wedges made from scrap

[266] McCarthy 2005, 97; see also Petrie 1917, 39, Pl. XLIII; Manning 1985, 16-7, Pl. 9; Ulrich 2007, 21, 36-7, 342.
[267] Hocker 2004a, 321; see also Horsley 1978, 142-45, Fig. 48. Finderup (2006, Fig. 4.6) presents photographs of tool marks from a plane on a plank of the Viking Age Roskilde 6 wreck as well as on a plank from the modern Skuldelev 2 reconstruction. No such tool marks were found on any of YK 14's timbers. Van Holk (2006, 298) also states that the three planes found on the de Meern 1 barge would have been used for fine carpentry such as furniture making rather than shipbuilding. Planes were used since at least the first century C.E.—the earliest known archaeological examples are from Pompeii—and many Roman Imperial period finds of planes are known, so it is possible that they were sometimes used by Byzantine carpenters and shipbuilders, but the more versatile adze must have been preferred (Ulrich 2007, 41-5, 344-47).
[268] Ulrich 2007, 57. Myrhøj (2004) presents archaeological examples of medieval planking clamps from the twelfth- to early fifteenth-century planking from Denmark and Poland; clamps are also illustrated in

wood would have been used to support the keel and other hull elements during construction. These also are unlikely to have left any traces of use on the hull other than evidence of nails or treenails used to temporarily fasten props in place during construction; this may explain some of the plugged fastener holes in the keel and planking timbers, many of which have no other clear purpose.

The sets of carpenter's tools from the seventh-century Yassıada and the eleventh-century Serçe Limanı shipwrecks offer specific examples of the tool sets required by a ship's carpenter in the Byzantine period. On the Yassıada shipwreck, assemblage of tool concretions found near the ship's galley and thought to have belonged to the ship's carpenter, included a slot adze, a chisel, a gouge, two drill bits, a carpenter's compass, two files, and three nails; additionally, seven billhooks, four axes, two mattocks, four more adzes, four hammers, five more chisels, a second gouge, two punches, a third drill bit, an awl, and five knives were found elsewhere on the ship. While many of these tools are foraging rather than carpentry tools, some were also likely intended for ship construction and repair.[269] According to Hocker, the tool assemblage from the Serçe Limanı shipwreck is the "most complete from any medieval site, shipwreck or otherwise, from the Mediterranean."[270] As with the seventh-century Yassıada ship, many

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Nicolas Witsen's shipbuilding treatise from 1671 (see also Hoving 2012, 27, Fig. 1.19, 61, Fig. 2.45). Similar clamps could have been used in Byzantine ship construction as well.

[269] The billhooks, axes, and mattocks were probably used primarily for foraging for firewood for the galley hearth (Katzev 1982, 265).

[270] Hocker 2004a, 320. Another important tool assemblage is that from the Ma'agan Mikhael wreck from c. 400 BC: despite the difference in age, the tools from the Ma'agan Mikhael ship are remarkably similar to those used in later periods and even to modern woodworking tools. This assemblage included five chisels, two possible tanged awls, three or four bow drills, two mallets, a ruler, a set square, a plumb bob,

of the Serçe Limanı carpentry tools were stored separately from the foraging tools—in the latter case, in a basket in the stern, associated with a whetstone and nails—which suggest private ownership on both vessels.[271] The Serçe Limanı carpentry tools included three slot adzes, two drill stocks and seven iron drill bits, five bar chisels, a hammer, a beetle or mallet head, a nail set, two nail-puller/claw hammers, a rasp, a saw blade fragment, four caulking irons, a reefing tool, and a plumb bob; further forward were found two adzes and most of the caulking irons.[272] Several carpentry tools similar to those from Byzantine shipwrecks found off the coast of Turkey were also found on the tenth-century Agay 'Saracen' wreck, which included an adze, a pair of axes, a gouge, a burin, an auger, a nail puller, and a number of iron nails.[273]

These archaeological examples of tools used for ship carpentry give a clear idea of the types of tools that would be required for the construction and repair of YK 14. According to the seventh-century C.E. *Rhodian Sea Law*, profit shares for a ship's carpenter are listed, implying that he was normally on board at least some classes of merchant ships; a carpenter's presence was also recommended on warships in the *Taktika* of Leo VI, dating to c. 900.[274] Whether a ship's carpenter was part of the crew of

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and a whetstone; adzes and saws used in the construction of the hull based on tool marks were not found on the shipwreck (Udell 2003, 203-18).

[271] The absence of references to carpentry tools in later medieval contracts for the sail or charter of Mediterranean merchant ships and in the tenth-century Byzantine naval inventories in the *Book of Ceremonies* suggests to Hocker (2004a, 321) that carpentry tools were normally private property of the individual craftsman, a practice which continued into modern times.

[272] Hocker 2004a, 297-313.

[273] Ximenes 1976, 148, Pl. IV, 1-3, 5-8, 10, and Fig. 14-6, 18-22; see also Hocker 2004a, 308-9, Fig. 18-7 (T 21-2).

[274] Ashburner 1976, 57; see also Pryor and Jeffreys 2006, 487. In Leo VI's *Taktika*, the author recommends that "A shipwright should be on board with all his tools, some of forged metal such as an

YK 14 can probably never be known, but the ship almost certainly carried at least basic carpentry tools for repairs during its sea voyages. If such tools were on board YK 14 when it sank, they were probably scattered in the harbor at that time or were salvaged soon after sinking.

In addition to woodworking tools, at least some basic measuring tools were likely used in the ship's construction. Hocker states that the primary measuring tools for a Mediterranean shipbuilder of the early medieval period consisted of a carpenter's square, compass, calipers, and line level or plumb bob.[275] A shipwright's ell or measuring stick may have been used to determine at least the basic dimensions of the hull; in traditional shipbuilding the lengths of such a measuring stick is often unique to a shipyard or individual builder.[276] Folding bronze rulers are known from the Roman period, although the cheaper, simpler wooden rulers are much more likely to have been usual for ship construction and common carpentry work.[277] Carpenter's compasses were excavated from the seventh-century Yassıada ship and one of the first-century CE Nemi barges,

adze, a drill, a saw, and the like" (Dennis 2010, 505). Hocker suggests that this statement may indicate that occasionally ships traveled without a proper set of carpentry tools, although Pryor and Jeffreys note that Leo VI, who in their opinion actually was the author of the *Taktika*, had no practical experience in leading fleets, relied primarily on older sources in writing the chapter on naval warfare in the *Taktika*, and tended to state what would be obvious to professionals throughout the work (Pryor and Jeffreys 2006, 66-7, 175-76, 180-81). Ashburner (1976, liii) believes that the *Rhodian Sea Law* was compiled no later than 800, "and probably a good deal earlier"; Makris (2002, 95) ascribes the text to the sixth- or seventh-century and states that it is a "digest of earlier provisions."

275 Hocker 2004a, 313.

276 Christiansen 1972, 237-40; see also Lemée 2006, 41. The *Codex Palatinus Graecus* 367 from the Vatican Library, a thirteenth-century text from Cyprus probably copied from a much older source, contains a section on measurement of ships' hulls, which includes the statement that "The marine measuring rod should be rounded, fashioned by hand and made from boxwood" (Harpster and Coureas 2008, 8-9, 11, 13, 19).

277 Goodman 1964, 188-90; Ulrich 2007, 54-5.

and they also appear in Roman art.[278] Calipers are known from the sixth-century B.C.E. Archaic Greek shipwreck from Giglio.[279] A set of carpenter's tools from the Classical-period Ma'agan Mikhael wreck also included a ruler, a carpenter's square, and a plumb bob.[280] A number of these tools are also known from archaeological and iconographic sources. Levels, rulers, and plumb bobs are known from examples in Roman art as well as from archaeological examples from the Ma'agan Mikhael and Serçe Limanı shipwrecks.[281] Carpenter's squares are also known from Roman art, particularly funerary stelae, archaeological examples from Pompeii and Neftenbach in Switzerland, and Roman period literary references.[282] The possible applications of such tools in the construction of YK 14 will be discussed further in Chapter IV.

In summary, the tools required to construct the ship's hull would have included axes and a frame or rip saw for the initial felling of trees and rough shaping of logs; adzes and smaller bucksaws and/or handsaws for further shaping of timbers; a bow drill for drilling fastener and pilot holes; hammers for driving nails, mallets for driving treenails and coaks and perhaps for hammering edge-fastened hull planks together; chisels for cutting mortises, grooves, scarf ends, and other precise work; and knives or drawknives for making wooden treenails and coaks from tree branches or other wood scraps. A

[278] Ucelli 1950, 189, Fig. 207; Ulrich 2007, 52.
[279] Bound 1991, 31.
[280] Stieglitz 2006; Udell 2003, 210-2. Stieglitz (2006, 195, 202-3) suggests that at some of these tools may be those of an architect rather than a shipwright, who would not require measuring tools with the different standards of linear measurements found on the builder's square and ruler.
[281] Ulrich 2007, 46, 53-4; see also Goodman 1964, 188-90; Udell 2003, 210, 212; Hocker 2004a, 313, Fig. 18-8.
[282] Ulrich 2007, 55-7.

carpenter's ell or measuring stick, square, and plumb bob or level for basic measurements of lengths and angles may also have been used. Other tools could have potentially been used in the ship's construction, but no evidence of their use has survived.

Fasteners: Iron Nails

Although wooden treenails and coaks were the primary fasteners used in the hull of YK 14, iron nails were employed throughout the hull to fasten planking and stringers to frames, frames to keel timbers, and the garboards and planking hood ends to the keel and endpost timbers. Nails were most frequently utilized to fasten frames to the keel or hull planks to the frames in the turn of the bilge area. The nails themselves generally did not survive, although original dimensions of many examples were preserved in nail holes in the wood and iron concretions. In most cases, exposed sections of the nails were reduced to gray-colored iron concretions resembling the sand surrounding the shipwreck, and crumbled easily; only a small proportion of the nail head concretions removed from the hull contained well-preserved molds retaining the original surfaces. Despite their poor condition, the nail concretions could generally provide fairly accurate dimensions of nail shafts and nail heads. The diameters of the nail shafts and heads were often well preserved on the timbers themselves; nail heads left impressions in the wood, while nail shafts were clearly visible in the wood once excess concretion was removed. In some rare cases, a solid nail-shaft concretion remained in the timber, but most nails had corroded completely into a granular, iron-sulfide corrosion product that could be removed from the nail hole by spraying it with a water bottle and gently probing the hole with a wire or dental pick. Due to the complete conversion of the iron nail shafts to a ferrous-sulfide-based slurry in the nail holes, minimum depths of nail holes could be measured with a steel wire in many cases.[283] Measurements using this method must be treated with caution in areas where the wood was particularly soft, but due to the generally excellent preservation of the hull timbers, these cases were infrequent. Another potential source of inaccuracy is the bending or curving of nails while being driven into the wood; this can occur due to features of the wood structure in the timber itself, such as differences in density or hardness.[284] Based on these factors, measured nail lengths from YK 14's hull should be considered minimum or approximate nail lengths unless otherwise noted.[285]

Although iron nails of different lengths are represented in the hull of YK 14, the cross-sections of the nail shafts and the dimensions of the nail heads, when measurable, were generally of similar sizes. The nails used in fastening the frames to the planking were driven from the outside of the hull. Nail head dimensions of these planking nails obtained during cataloging were remarkably consistent, with nail head diameters ranging

[283] For the corrosion of iron in underwater archaeological contexts, see Hamilton 1999, 38-42.
[284] Bass et al. 2004, 107.
[285] In a few cases, a much more accurate nail length could be obtained. The shaft of a nail driven into FL 10 to fasten a repair plank (PS 3-1A) was exposed by a split in the frame, which allowed its complete depth in the frame to be measured (5.2 cm, giving a total length of the nail in the range of approx. 8.2-8.4 cm, based on PS 3-1A's planking thickness of 2.7 cm at FL 10, and assuming a nail head thickness of 0.3-0.5 cm). The keel nail of FL 47, whose shaft was preserved as an iron concretion because the frame was pulled out of the ship during its sinking, the nail's length was estimated as 12 cm based on the nail shaft concretion and the molded dimensions of the frame at the keel nail.

from 1.8 to 3.0 cm, with an average diameter of 2.3 cm.[286] The nail shafts just below the heads of these nails (where they were preserved) ranged from 0.7 to 1.2 cm in cross section, with an average of 0.8 cm to a side; more than half of those measured were 0.7-0.8 cm in cross section.

The nails used in fastening the floor timbers to the keel were slightly larger. Of the 45 surviving floor timbers of YK 14, 19 were nailed to the keel from the inside of the hull. Of these floor timbers, 14 (FL 9, 12, 14, 23, 24, 26, 32, 35, 38, 41, 43, 45, 46, and 47) yielded dimensions from nail heads. The tapered shafts of the nails typically had a square or rectangular cross section ranging from 0.7 to 1.0 cm just below the head. In many cases, some dimensions of the original nail head were preserved, based on the survival of a nail head concretions and/or nail head impressions in the wood. Keel nail heads ranged in diameter from 1.2 to 2.8 cm, with an average diameter of 2.5 cm, and approximate minimum thicknesses of 0.3-0.6 cm, with an average minimum thickness of 0.4 cm. Based on the concretions of nail heads removed from the outer faces of the hull planking, the head thicknesses of the planking nails were similar.

[286] Nail-head diameters for 43 planking nails were obtained primarily from nail head impressions on the outer faces of planks. These were obtained only from small planks or broken pieces of larger timbers, and in a few cases from nail head concretions. Measurements of the nail shaft just below the head were also obtained from the outer face of planking in 33 cases. Although many nail concretions were recovered from the outer faces of the hull planks during the excavation, they have yet to be fully examined. Several dozen nail head concretions were also recovered, but the nail head impressions in most of the concretions were poorly preserved. The concretions themselves were not particularly solid; between the excavation of YK 14 in the summer of 2007 and the cataloging of the planking from 2009 to 2012, many of the concretions had crumbled completely while in storage. Concretions of the keel nail heads were also generally poorly preserved, but a few better-preserved examples were recovered. In the future, some of the best preserved of these concretions could be cast in epoxy to obtain nail head dimensions of more of the planking nails; but, overall, it appeared that more accurate diameter dimensions would be obtained from nail head impressions in the surfaces of the timbers.

Caulking fibers, apparently of grass, were found in many of the nail holes in the planking; the fibers had been wrapped around the nail shafts just below the head in an attempt to waterproof the fastener hole. This was a particularly common feature with nails driven into clearly distinguishable pilot holes (**Figure 3.19**). Thirty-two examples of this feature were noted in nail holes and nail concretions, with 16 occurring on certain or probable repair fasteners. It is unclear why they are so frequent on repair pieces, but it is likely related to better preservation of the waterproofing materials on many of the repair pieces; many of which can be assumed to have been exposed in the hull for significantly less time than the original timbers. Deep pilot holes were also routinely used for nails fastening repair components.[287] This waterproofing method was observed in the hulls of several other shipwrecks from Yenikapı, and similar methods were used on other shipwrecks and in documented shipbuilding practices from later periods.[288]

[287] In documenting YK 14, it was not possible to examine the outer faces of all hull planks for such features, due to the large size (some over 6 meters long) and sometimes pronounced curvature of many of the intact planks. However, the outer faces of smaller planks and fragmentary planks were examined in many instances, and sufficient examples of pilot holes were observed to consider it a normal practice in the construction of the hull.

[288] Similar wrappings or plugs of caulking were found under iron nail heads on the YK 5 and 11 shipwrecks, as well as on nails and an iron bolt from the Serçe Limanı shipwreck, as noted by Steffy (Bass et al. 2004, 86, 110). Wrappings of hazel twigs soaked in pine pitch were discovered under the nail heads of the second-century C.E. Blackfriars ship (Marsden 1994, 33, 61). Strands of cotton are commonly wrapped below the nail head for waterproofing in modern dhow construction in the Persian Gulf (Agius 2002, 145). Oakum plugs are recorded as being used on the ends of treenail holes in Mainwayring's *Seaman's Dictionary* (1644) and in later sources (Alston 1972, 23, 71; McCarthy 2005, 66). 'Oakum washers' were also inserted just below the heads of forelock bolts used in the construction of fifteenth and sixteenth-century Iberian ships (Smith 1993, 67).

Figure 3.19: The outer face of plank SS 6-2/1-1A at the location of floor FL 25, where a nail head impression in pitch was preserved. Note the caulking fibers preserved in the concretion that were originally wound around the base of the nail shaft under the head. This nail was probably used as a repair nail.

Based on the probing of nail holes, the observations of the lengths of nail shafts from breaks in the timbers, and other features, it appears that two main types of nails were used. A shorter, more common type with a length of approximately 7-9 cm was used to fasten planking and stringers to frames, and for repairs.[289] Longer nails or spikes, with estimated minimum lengths of 10-12 cm, were used to fasten some floor timbers to the

[289] Holes from nails used in securing planking to the frames ranged in depth from 1.5 to 7.1 cm, with an average depth of 3.8 cm. The total lengths of the planking nails is, therefore, probably in the range of 4.4-9.2 cm, with an average minimum length of about 6.7 cm. This estimate was reached by adding 2.5 cm (for the thickness of the plank) to the nail hole depths in the frames, and 0.4 cm for the thickness of the nail head.

keel,[290] as was the case with many other Yenikapı ships. Nails of similar sizes could have been used in the upper works of the ship to fasten frames to wales or wales to deck beams, but no such evidence exists in the surviving portion of YK 14's hull.

The two basic sizes of nails used in YK 14 roughly correspond to nail sizes seen on other shipwrecks from Yenikapi, including YK 1, 2, 4, 5, 11, 23, and 24. Unlike some of the other Yenikapı roundships, such as YK 1 and 5, only treenails were used to fasten the wale to the frames on YK 14, rather than a combination of treenails and nails. Fastening the wales to the frames would have likely required a larger-sized nail than those used on planking. These nail sizes are also consistent with iron nails used in the construction of many other excavated Roman and Byzantine shipwrecks.[291] Several tenth-century Byzantine texts, including a manual on siege warfare and two inventories for naval expeditions to Crete, indicate that iron nails were produced in standardized

[290] This length estimate is based on probing of frame-nail holes (when the holes were not too concreted to probe) in the inner face of the keel timbers, the molded dimensions of the frames at the keel nails, and an estimated minimum thickness of the nail heads obtained from nail head concretions or their impressions on the floors.

[291] Nails from the seventh-century Yassıada shipwreck had shafts of 0.5-1.0 cm in cross section, nail heads of 2-3 cm in diameter with flat or "moderately curved" section, and lengths from 3.7 to 4.7 cm for 'tacks' (possibly used in the upper works of the hull), and 6.0 to 17.1 cm-long nails to 26 to 37 cm-long spikes for fastening frame timbers to the keel, based on probing nail holes in the keel (van Doorninck 1982, 56-7; Katzev 1982, 252-55). On the Serçe Limanı ship, two sizes of nails were also used. Nails used to fasten the floor timbers to the keel exhibited shafts ranging from 0.8 to 1.2 cm to a side and nail heads typically around 2.5 cm but sometimes as large as 4.0 cm; where measurable, these nails ranged in length from 12 to 16 cm long (Bass et al. 2004, 98). Nails used to fasten planking to the frames were smaller, with shafts ranging from 0.6 to 0.8 cm to a side (but showing a fair degree of variation), nail heads averaging 2.2 cm in diameter, and lengths of 12 to 16 cm where they could be measured; in a preliminary report on the shipwreck, Steffy states that nail shafts visible at breaks in the frames are about 10 cm long, and that the planking nails used in the hull were probably about 13.5 cm (Steffy 1982b, 23; see also Bass et al. 2004, 98). Matthews and Steffy (in Bass et al. 2004, 98) note that, based on nail concretions protruding from the outer face of the Serçe Limanı ship's keel, some nails used in fastening the frames to the keel may have protruded from the outer face or were driven nearly to the outer face. This did not occur on YK 14 except in locations where a pilot hole was drilled through a scarf. On the ninth-century Bozburun ship, the shafts of the iron nails also had similar cross-sectional dimensions to those from YK 14 and other Byzantine ships (Harpster 2005a, 108, 129).

lengths for specific purposes; different nail head shapes are specified in some instances as well.[292] These texts indicate that nails were frequently distinguished by their length in 'fingers' or *dactyloi*, of approximately 1.95 cm each.[293] The 'four-finger' nails seem to correspond well to the nails used to fasten the frames to the planking on YK 14, while longer nails, possibly 'six-fingers' (11.7 cm) in length, were used for nailing frames to the keel and possibly in other areas where larger nails were needed.[294]

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[292] Based on contemporary documents, the Byzantine state bureaucracy and military recognized a large number of iron fastener types. Nails are included in a pair of inventories of supplies requisitioned for two naval expeditions to Crete in 911 and 949 preserved in the *The Book of Ceremonies* from the reign of Constantine VII. The 949 inventory lists 4,000 "round/flat-headed nails", 2,000 "claw-nails", 5,000 'four-finger-long' [spikes] (7.8 cm, based on Schilbach's Byzantine *dactyl* of 1.95 cm), 6,000 'deck nails', and 8,000 '[spikes] for fastening' (Pryor and Jeffreys 2006, 563, 569; see also Schilbach 1970, 16-19; Haldon 2000, 232). The earlier part of the inventory, from the 910-911 expedition includes a list of requisitions from various themes. Among the supplies from the Thrakesion theme, "6,000 nails for the nailing of the *dromones*, 30,000 five-finger (9.75 cm) nails for the decking of the *dromones*, for the gangplanks and stalls, as well as 3,000 "single-headed claw-nails for 'tortoises'/sheds, ladders and other jobs, and the 3,000 handspan nails (12-finger, or 23.4 cm)," as well as 4,000 six-finger (11.7 cm), 4,000 five-finger (9.75 cm), and 4,000 four-finger (7.8 cm) nails for the derricks and the walkways and other needs" (Haldon 2000, 210, 228; Pryor and Jeffreys 2006, 552-3; Schilbach 1970, 19). A purchase of 60,000 "small nails for fastening the hides" (for fireproofing?) is also mentioned in the 911 inventory (Haldon 2000a, 210; see also Christides 2001, 136). Many of these nail categories seem to be intended for siege engines and other siege equipment, or for uses specific to the equipping of dromons, which required a number of specialized structures and equipment; unfortunately, the exact nature of many of the items on the inventories is difficult to determine due to the specialist terminology used. For the difficulties in translation of this document, see the commentary in Haldon 2000, especially p. 236-8 and 268-70. A tenth-century Byzantine manual on siege warfare, the *Parangelmata Poliorcetica*, also contains the following in a passage on materials necessary for constructing a 'tortoise' for approaching enemy fortifications: "…flat-headed nails 8 *daktyloi* long [15.6 cm], that is, small iron spikes, should be driven from above into the slanting beams of these tortoises to a depth of 4 *daktyloi* [7.8 cm]…" (Sullivan 2000, 49). In modern dhow construction in the Persian Gulf, similar categories of nails are used, with the two longest categories used for fastening frames to the keel (16" /40.64 cm) and planking to the frames (10" and 12" /25.4-30.5 cm nails), and smaller types for other purposes (Agius 2002, 143).

[293] Schilbach 1970, 16; see also Haldon 2000, 210.

[294] Matthews and Steffy note that many of the nails used to fasten the floor timbers to the keel on the Serçe Limanı ship protruded from the outer face of the keel (Bass et al. 2004, 86, 98). Since the keel of this vessel had molded dimensions of approximately 14-17 cm and the molded dimensions of the floor timbers over the keel were also approximately 14 to 17 cm, 'handspan' nails (23.4 cm long) or slightly longer nails were likely used for this purpose, in contrast to the smaller nails used on YK 14 (Bass et al. 2004, 85, 89-92; Schilbach 1970, 19). The heavier fastening of the Serçe Limanı ship in comparison to YK 14 may reflect different functions or designs for different sailing conditions for the two vessels, a hypothesis which is discussed in more detail in Chapters IV and VII.

Iron nails were used sparingly on YK 14. Of the surviving frame timbers, eight floors and ten futtocks were fastened to the planking exclusively with wooden treenails. At frame stations where nails were also used to fasten the frames to the planking, there are typically several treenails used for every iron nail, with a large proportion of the nails in evidence representing repair or possible repair fasteners.[295]

Unlike many other Byzantine shipwrecks, little evidence for the use of iron bolts as fasteners was found in YK 14; only one probable bolt appears to have been used in the surviving section of the hull.[296] Two predrilled fastener holes in the aft scarf of Keel 3 were found to contain iron fasteners with rectangular cross sections of 0.5 and 0.8-1.3

[295] My observations during the cataloging of hull timbers from YK 14 support the suggestion by Liphschitz and Pulak (2009, 167-68) that many of the nails in the hull are likely from later maintenance or repairs rather than original features of the hull (see Table 3.1). Several of the roundships excavated by INA at Yenikapı show similar evidence of the extensive use of iron nails for hull repairs. Many more iron nails were used in the heavily repaired hulls of the tenth-century roundships YK 1 and YK 24 than in YK 14's hull, and were often driven near or through treenails. On the other hand, similar numbers of nails to those in YK 14 were used in the hull of the tenth-century cargo ship YK 5, which was nonetheless a newer ship when it sank, having no repair planks or significant damage from rot on the inside of the hull. In the galleys YK 2 and YK 4, nails were used throughout the hulls. Since YK 2 was almost certainly a fairly new ship when it sank—no clearly identifiable repair timbers were found in its hull—it is likely that this was standard practice in galley construction. Galleys in all periods were kept out of the water whenever possible in order to avoid marine growth on the hulls. Perhaps corrosion of iron nails may have been more easily removed or dealt with on ships that were intended to be beached daily or have a shorter lifespan than merchant ships; or, the structural advantages of iron nails may have been thought to outweigh the disadvantages (Dennis 2010, 515-17; see also Veg., *Mil*. IV.34; Coates 2001, 154, 158, 161-62).

[296] This is in marked contrast to other Byzantine-era shipwrecks from Turkey (van Doorninck 1982, 55, 57-8, see also Katzev 1982, 256-58; Hocker 1998, 9; Bass et al. 2004, 86, 164). During the excavation of vessels such as the later tenth-century C.E. merchant vessel YK 5, it was found that it was easy to misinterpret nails fastening frames to keel timbers as bolts. This was due to predrilled pilot holes for the nails in the floors: the 'bolts' were in fact nails whose concretions formed a cylindrical plug in the drilled pilot hole resembling a bolt shaft. Iron bolts were rarely used in the construction of the INA-documented ships from Yenikapı, usually occurring only at keel scarfs. One forelock bolt, presumably for a keelson, was found between frame positions on YK 4, a tenth-century galley; this fastener was 1.7 cm in diameter, with a bolt head approx. 3.3 cm in diameter and at least 0.5 cm thick, and was approx 34-36 cm long, with the head preserved in a countersunk recess on the outer face of the keel. Similar bolts were used to fasten a hook scarf in the keel timbers of the seventh-century YK 11 wreck and the tenth-century YK 1 wreck, both small cargo vessels.

cm, respectively. An iron concretion was found covering both fastener holes, with a depression inside that was possibly the poorly preserved mold of the original fastener head; the wear pattern on the outer part of the keel also suggests that the aft fastener had a large head, possibly from a large spike or forelock bolt. However, the shaft of the larger of these fasteners is smaller in diameter than most of the bolts used in the construction of several ships excavated at Yenikapı and bolts used in the keels of the Serçe Limanı and seventh-century Yassıada wrecks.[297] The Keel 3 fasteners could be large nails or spikes used to secure the keel/post scarf at this location, or else also fastened a frame or longitudinal timber above the scarf. Spikes for this purpose would probably be over 15-25 cm long, large in terms of the other fasteners found on YK 14 but fairly common for iron fasteners from other Roman and Byzantine shipwrecks. The molded dimension of the keel at the location of these fasteners was approximately 15 cm. If these nails were clenched or driven through a floor timber at this location, they would likely have been at least a few centimeters longer. However, if the head was under the hull, it seems difficult to drive a spike from below, even with a pilot hole, a feature which suggests that the aft fastener was for a forelock bolt to secure the Keel 3/stempost scarf.

[297] Examples of bolts from other Byzantine wrecks have shafts of 1.2 to 2.0 cm or more in diameter. On the seventh-century Yassıada ship, they ranged from 1.8 to 3.5 cm in diameter, with an average of 2.0-2.4 cm and a smaller diameter of 1.4-2.0 cm at the end opposite the head (van Doorninck 1982, 57). On the Serçe Limanı ship, bolts were 1.2-2.0 cm in diameter with 3-4 cm diameter heads (Bass et al. 2004, 86).

In spite of many ambiguous cases, repair fasteners can be identified in a number of areas.[298] A distinct concentration of nails and nail holes at the turn of the bilge area amidships on the starboard side (between FL 24 and FL 38) is due largely to repairs, and repair planks and probable repair fasteners also occur in the same area on the port side. This is also the area of the hull with the sharpest turn of the bilge, where the majority of repair planks were installed, and where hull planks tend to be narrower. Based on the absence of pitch as well as obvious wear on the outer faces of the planks at the turn of the bilge, these areas were likely subject to more wear, probably resulting from frequent beaching. Worn breaks on many of the coaks exposed on plank seams at the turn of the bilge indicate that they were broken in antiquity. Some of these breaks may have occurred during the wrecking of the ship, but others could have occurred earlier. Much of the worst damage from fungal rot also seems to have occurred at the turn of the bilge area, perhaps due to the pooling of bilge water in these areas as the ship heeled. Many of the nails found in these areas of the frames may have been inserted to repair rotten treenails or other rotten areas (**Figure 3.20**). Additional nail holes in floors at the turn of the bilge in the location of repair planks such as PS 6-2/1 and PS 6-2/2-4 suggest that

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[298] Repair fasteners naturally include nails and treenails used to fasten repair planks. Well-preserved fasteners in rotten areas, particularly when they are adjacent to broken or rotten fasteners, are almost certainly repairs as well. Steffy states that conclusive proof that nails and treenails in the Serçe Limanı ship were driven at a later date during an overhaul is "virtually impossible", but suggests that the identification of fasteners as later additions to the hull could be based partly on placement; for example, treenails appear to have been driven in areas away from nearby planking nails, indicating that they were driven later. Many of the repair nails in YK 1 were driven next to treenails; this may have been done to fasten treenails loosened by the working of the ship more securely as well as tightening the frames to the planks (Liphschitz and Pulak 2009, 167). On YK 14, a number of probable repair nails in the turn of the bilge and garboard areas are fastened in or next to treenails or treenail holes that were damaged by wood rot.

these nails may have been used in early attempts at repairing damaged areas, while at a later time the damaged section of the hull was replaced with a new plank.

Figure 3.20: Evidence for repairs on SS 6-2.1-1A under FL 25, a strake at the turn of the bilge on the port side. Pitch was applied under the frame and in a rotten area along the keel edge of the plank, and a nail was driven through the treenail fastening the plank to FL 25. Two repair planks are also located in the immediate vicinity of this original plank.

The following table (**Table 3.1**) lists the fasteners used in securing frames to the hull planking and fastener holes in the surviving hull planking at frame locations. The table clearly shows that both nails and treenails were used as repair fasteners, and that repair fasteners as well as suspected repair fasteners, particularly nails, tend to be clustered at the turn of the bilge area of the hull.

Table 3.1: Frame Fasteners[299]

FR No:	Total Tree-nails:	Repair Tree-nails:	Total Nails:	Keel Nail? (Y/N):	Orig. Nails:	Repair Nails (Strake/ Plank):	Possible Repair Nails (Strake/ Plank):	Notes:
FL 1 (Pl. only)	2 (poss.)	-	2	-	2	-	?	Possible location of hood ends rather than a floor timber
FL 2 (Pl. only)	2	-	-	-	-	-	-	
FL 3 (Pl. only)	2	-	-	-	-	-	-	
FL 4	5	-	-	N	-	-	-	
FL 5	8	-	-	N	-	-	-	
FL 6	10	-	1	Y	1	-	-	
FL 7	10	-	0	N	-	-	-	
FL 8	10	1	2	N	-	2	-	**Repair Fasteners**: N-1, TN 5 (PS 2-1/3 fasteners); N-2 (Keel/garboard fastener driven into frame in the area of the keel)
FL 9	13	1	1	Y	1	2	-	**Repair Fasteners**: N-1, TN 6 (PS 2-1/3 fasteners); "TN 9" (Keel/ garboard nail in a pilot hole driven into keel area of frame). TN 10 is a drilled fastener hole repaired with caulking
FL 10	13	-	1	N	-	1	-	**Repair Fasteners**: N-1 (PS 3-1A)
FL 11	10	1	1 (poss.)	Y	1 (poss.)	-	-	The keel fastener hole is heavily concreted; it is probably a nail in a shallow pilot hole. FL 11 broke at the keel at the pilot hole for the keel nail
F 11	7	-	-	-	-	-	-	
FL 12	17	-	1	Y	1	-	-	

[299] This table includes fasteners for floor timbers or futtocks that did not survive in the hull. The "Repair Fasteners" columns represent treenails and nails that were clearly used to fasten replacement components in the hull. "Possible Repairs" include fasteners driven through or adjacent to each other; well preserved treenails or nails driven into other fasteners or into rot-damaged areas in which treenails were clearly damaged by rot, or other possible evidence of repair. In many cases the status of a fastener as a possible repair is conjectural and cannot be proven.

Table 3.1. Continued

FR No:	Total Tree-nails:	Repair Tree-nails:	Total Nails:	Keel Nail? (Y/N):	Orig. Nails:	Repair Nails (Strake/ Plank):	Possible Repair Nails (Strake/ Plank):	Notes:
FL 13	9	-	-	N	-	-	-	
F 13	11-12	1 (poss.)	-	-	-	-	-	2-3 treenails driven into each other at PS 14 area (3 holes are visible in PS 14 planking, but only 2 treenails are visible on frame). One is a fastener for stringer ST-1
FL 14	19-20	-	1	Y	1	-	-	
FL 15	12	-	-	N	-	-	-	
F 15	10	1 (poss.)	-	-	-	-	-	TN 3 is driven through TN 4 in the PS 14 area; it is possibly a fastener for ST-1, or a repair
FL 16	18	-	-	N	-	-	-	
FL 17	13	-	1	Y	1	-	-	
F 17	10	-	-	-	-	-	-	TN 3 or 4 at PS 14 location could be a stringer fastener
FL 18	19	-	2	N	-	-	2 (SS2, SS 6)	TN 15 is a caulked hole in SS 3-2 located only on the planking. TN 8A in the PS 5 area is found on the inner face only
FL 19	16	1	-	N	-	-	-	**Repair Fasteners:** TN 13 (PS 5A/1-1A)
F 19	11	1 (poss.)	-	-	-	-	-	TN 2 or 3 at PS 14 location may have been an ST-1 fastener (drilled through TN 4). Either TN 2 or 3 is likely a repair
FL 20	23	1	5	Y	1	-	4 (PS 6, PS 5A, SS5, SS 6)	**Repair Fasteners:** TN 10 (PS 5A/1-1A)
FL 21	17	1	1	N	-	-	1 (SS 1)	**Repair Fasteners:** TN 14 (PS 5A/1-1A)
F 21	10	-	1 (+1 poss.)	-	2	-	-	TN 5 is a stringer fastener for ST-1 (PS 14 area)

Table 3.1, Continued

FR No:	Total Tree-nails:	Repair Tree-nails:	Total Nails:	Keel Nail? (Y/N):	Orig. Nails:	Repair Nails (Strake/ Plank):	Possible Repair Nails (Strake/ Plank):	Notes:
FL 22	25	1	1	N	-	-	1? (PS 6)	**Repair Fasteners:** TN 12 (PS 5A/1-1A). TN 18 A is a drilled hole in the outer face of the floor, probably from construction (?) (SS 1 location)
FL 23	16	1	3	Y	1	-	2? (SS 5, SS 6)	**Repair Fasteners:** TN 14 (PS 5A/1-1A)
F 23	10 (+2 drilled holes)	-	-	-	-	-	-	TN 3 fastened stringer ST-1 to F 23 in the PS 14 location. TN 6 in the PS 12 area is a drilled hole, but does not reach the inner face
FL 24	24	-	10	Y	3	1	6 (PS 5A/2-4, PS 6, PS 7 (2 of 3)SS5, SS 6,)	**Repair Fasteners:** N-5 (PS 6-2/1). TN 10A is a treenail driven from the inner to forward face: a possible stringer fastener?
FL 25	18	-	6	N	1	3	2 (PS 7, PS 5A/2-4)	**Repair Fasteners:** N-2 ((PS 6-2/2-4); N-3 (PS 6-2/1); N-6 (SS 5-2A). TN 36 is a wedged treenail
F 25	9	-	2	-	2	-	1 (PS 7)	TN 2 on PS 14 fastened stringer ST-1 to F 25. Indentation around TN 10 on PS 7—the treenail may have been driven from the inside as a stringer/ceiling fastener
FL 26	24	-	6	Y	2	3	1 (PS 7)	**Repair Fasteners:** N-2, N-3 (PS 6-2/2-4); N-6 (SS 5-2A)
FL 27	23	-	1	N	-	-	1 (SS 6)	N-1 occurs at the scarf seam between SS 6-2/1-1A and repair piece SS 6-2A; probable repair fastener

Table 3.1, Continued

FR No:	Total Tree-nails:	Repair Tree-nails:	Total Nails:	Keel Nail? (Y/N):	Orig. Nails:	Repair Nails (Strake/ Plank):	Possible Repair Nails (Strake/ Plank):	Notes:
F 27	13	3-4 (poss.)	-	-	-	-	-	TN 4 on PS 14 was used to fasten stringer ST-1 to the futtock. Clusters of 3 drilled holes at upper end (PS 15 location— strake did not survive) and PS 14 area suggest 3-4 repair/additional fasteners
FL 28	24	1	6	N	-	3	3 (PS 7, SS 1, SS 5-2)	**Repair Fasteners:** N-2, N-3 (PS 6-2/2-4); N-6, TN 23 (SS 6-2A). TN 12 is a drilled hole with iron concretion inside in the PS 6 location—possible stringer/ceiling fastener?
FL 29	20	2 (+1 possible)	3	Y	1 (Keel)	1	1 (SS 5-2)	**Repair Fasteners:** TN 14 (PS 6-2/2-4—later rotted out); N-3, TN 26 (SS 6-2A); TN 27 drilled through TN 27A—repair? (SS 7 area); TN 27B is a drilled hole in FL 29's inner face in the SS 7 location: a stringer/ceiling plank fastener?
F 29	10	-	-	-	-	-	-	Grooved futtock for bulkhead. TN 3 on PS 14 is a fastener for stringer ST-1
FL 30	26	-	6	N	-	3	3 (SS 1, PS 7)	**Repair Fasteners:** N-3, N-4 (PS 6-2/2-4); N-6 (SS 6-2A)

Table 3.1, Continued

FR No:	Total Tree-nails:	Repair Tree-nails:	Total Nails:	Keel Nail? (Y/N):	Orig. Nails:	Repair Nails (Strake/ Plank):	Possible Repair Nails (Strake/ Plank):	Notes:
FL 31	15	-	8	N	-	2	6 (SS 4-2, SS 6—frame only, SS 7)	**Repair Fasteners:** N-4, N-7 (SS 6-2A). A caulked drilled hole in plank PS 6-2/2-4 does not match a frame fastener; it is from the original use of the plank
F 31	9	1 (poss.)	2	-	2	-	-	N-1 on the inner face of F 31 fastens stringer ST-1 to the frame (PS 14 area). TN 3 was drilled through TN 3A in the PS 14 location
FL 32	25	2	5	Y	3	-	2 (PS 7, PS 6)	**Repair Fasteners**: TN 10 (PS 6-2/2-4); TN 21B (SS 6-2A). Possible stringer/ceiling fasteners at PS 8 (TN 8A—frame only, with dimple/impression on inner face of plank; TN 8c, drilled hole in inner face of plank only). Two caulked holes in SS 6-2A are in planking only—from original use of plank
FL 33	14	-	5	N	1 (PS 5)	-	4 (SS4, SS 6-3)	
F 33	12	1-2 (poss.)	1	-	1	-	-	Cluster of 3 treenails (TN 3-5) at PS 14—possible repairs? TN 4A in the PS 14 area runs from the inner to the aft face—probable fastener for stringer ST-1
FL 34	23	-	5	N	-	1	4 (PS9-2/1-4, PS 6-3, PS 5)	**Repair Fasteners:** N-1 (PS 9-2/1-4, PS 9-2/5 scarf); N-5 (PS 4-3)

Table 3.1, Continued

FR No:	Total Tree-nails:	Repair Tree-nails:	Total Nails:	Keel Nail? (Y/N):	Orig. Nails:	Repair Nails (Strake/ Plank):	Possible Repair Nails (Strake/ Plank):	Notes:
FL 35	14	1 (+1 poss.)	4	Y	1	-	3 (PS 5, SS 4, SS 6)	**Repair Fasteners:** TN 16 (PS 4-3). TN 20 is a drilled hole in the SS 1 location found on the frame only; N-2 is a nail hole in the PS 5 location found on the frame only
F 35	12	1	1	-	1	-	-	**Repair Fasteners:** TN 8 (PS 9-2/5). TN 3 was driven through PS 14-2/2-6's aft scarf end
FL 36	25	1 (poss.)	9	N	3	1	5 (PS 8, PS 7, PS 6, PS 5)	**Repair Fasteners:** N-7 (PS 4-3). TN 23 was driven through TN 24 on SS 6-3; possible repair treenail
FL 37	16	1 (poss.)	4	N	1	2	1 (SS 6)	**Repair Fasteners:** N-3, N-3A (PS 5-2). TN 12 on PS 7 is next to a caulked hole, possibly a repair or temporary fastener hole from construction
F 37	10	-	2	-	2	-	-	Futtock grooved for bulkhead
FL 38	28	1 (+1 possible)	7	Y	-	-	5 (PS 12—2 nails, PS 11, PS 6, SS 6)	**Repair Fasteners:** TN 16 (PS 5-2). TN 10 in the PS 10 area does not appear on the plank—possibly a stringer or ceiling treenail? TN 25 is driven through TN 24 in the SS 4-2 area—possible repair? N-1 to N-3 (PS 11, 12 area) are likely repairs—there is severe dry rot damage on the outer face of FL 38

Table 3.1. Continued

FR No:	Total Tree-nails:	Repair Tree-nails:	Total Nails:	Keel Nail? (Y/N):	Orig. Nails:	Repair Nails (Strake/ Plank):	Possible Repair Nails (Strake/ Plank):	Notes:
FL 39	13	1 (poss.)	2	N	-	1	1 (PS 5)	**Repair Fasteners**: N-3 (PS 5-2). TN 24 is driven through TN 25 in the SS 6 area—repair treenail?
F 39	15	1 (poss.)	2	-	2	-	-	Unmatched treenails in futtock area in PS 5, PS 6 area (planking only). Temporary fastener holes from construction? TN 3 drilled through TN 4 in PS 13 area—possible repair or stringer fastener?
FL 40	19	2 (poss.)	5	N	1	1	3 (PS 11—2 nails, PS 6)	**Repair Fasteners:** N-2 (PS 5-2). Two nails in the planking on PS 11 (N-1A, N-1B) do not appear as fastener holes in the floor, but FL 40's outer face is severely damaged by rot in this area. TN 16-7 on SS 3 and TN 18-9 on SS 6 are adjacent treenails, with both visible on the outer face only; two are probable repairs. On SS 3 caulking was driven between the treenails
FL 41	10	1	3	Y	1	-	2 (PS 2, SS 6)	TN 22 on SS 6-3 is a re-caulked hole on planking—damaged, then repaired?

Table 3.1, Continued

FR No:	Total Tree-nails:	Repair Tree-nails:	Total Nails:	Keel Nail? (Y/N):	Orig. Nails:	Repair Nails (Strake/ Plank):	Possible Repair Nails (Strake/ Plank):	Notes:
F 41	11	1 (poss.)	1	-	-	-	1 (PS 11)	TN 8 was driven through TN 9 on PS 8: a possible repair? TN 10 in the PS 6 area is found on the planking only; from a temporary fastener used during construction?
FL 42	17	-	-	N	-	-	-	
FL 43	10	-	2	Y	2	-	-	
F 43 (Pl. only)	8	-	-	-	-	-	-	
FL 44	16	?	5	Y	1	4	-	FL 44 is a possible repair frame; a keel nail in Keel 3 is not found on FL 44, and the frame has unusual shape and scarf end
F 44 (Pl. only)	8	3-4 (poss.)	-	-	-	-	-	A line of caulked holes runs parallel to F 44 fasteners probably from the original floor: caulked holes in planking on PS 10A, 10B, 11-2/6, and 12-2 next to fasteners for F 44. F 44 may have been a repair
FL 45	8	-	2	Y	-	-	-	Caulked drilled holes in planking occur under floors at PS 2-2, PS 1-2, SS 1-3, and SS 2-2: a temporary cleat location?
F 45	7	-	-	-	-	-	-	
FL 46	14	-	4	Y	3	-	1 (PS 7)	
FL 47	16	-	1	Y	-	-	-	
F 47 (Pl. only)	6	3 (poss.)	-	-	-	-	-	TN 1, 2, and 3 are likely fasteners for a second futtock beginning at PS 9-3

Table 3.1, Continued

FR No:	Total Tree-nails:	Repair Tree-nails:	Total Nails:	Keel Nail? (Y/N):	Orig. Nails:	Repair Nails (Strake/ Plank):	Possible Repair Nails (Strake/ Plank):	Notes:
FL 48	10	1 (poss.)	4	N	-	-	4 (PS 8, PS 7, PS 6, SS 1)	TN 3 and 3A are adjacent treenails in PS 7: one is possibly a repair
FL 49 (Pl. only)	6	-	2	Y	-	-	1 (SS 1)	
FL 50 (Pl. only)	5	-	-	N	-	-	-	Two caulked holes at FL 50 (SS 1-3, PS 1-2)
FL 51 (Pl. only)	3	-	3	Y	2	-	1 (SS 1)	SS 1-3 nail is adjacent to a treenail: possibly a repair?
FL 52 (Pl. only)	1	-	1	Y(?)	-	-	-	Possible floor timber or futtock location at Keel 3's forward scarf end and the aft end of PS 6-3

Treenails

Wooden treenails were the primary fasteners used in securing frames to the hull planking in YK 14.[300] Over 500 treenails were sampled for wood species identification, all of which were identified as Turkey oak (*Quercus cerris*).[301] Treenail diameters ranged from 0.9 to 1.8 cm, but most have diameters of approximately 1.2-1.5 cm. The treenails are usually tapered, with the larger-diameter end located on the outboard side, indicating that they were driven from outside the hull. The original treenail lengths before insertion

[300] Coaks used as edge fasteners will be discussed separately in the section on planking.
[301] Liphschitz and Pulak 2009, 168. The large number of treenails sampled was due to the observation that the wood species of treenails used to fasten original frames sometimes differed from those used to fasten repair frames on the galleys YK 2 and 4. No such variation was found in the wood types for treenails used on YK 14 or any of the other roundships; all were made of Turkey oak (*Quercus cerris*), although significant variation was found in the wood species used to make coaks for edge fastening the hull planking (see Chapter VI).

would have been significantly longer; the excess length was cut off after they were driven home tightly.[302] White deposits were observed on the exterior surfaces of some treenails after extraction from their holes; one analyzed sample of this material was identified as containing degraded pine pitch (see Chapter VI). This material could have leaked into the treenail holes, but it is also possible that the treenails were lubricated with pitch before driving in place, a practice mentioned by Plutarch and also known from later European shipbuilding practice.[303] Treenails were polygonal in cross section and were originally shaped with an adze, but in many cases their edges became rounded by being forced into holes of the same or slightly smaller diameter.[304] Very few of the treenails on YK 14 were wedged or pegged, a feature that appears to be confined to treenails at or above the ship's waterline; only five examples were found during the cataloging of the timbers. All but one example are from UM frame timbers that probably originate from futtocks or top timbers in the upper part of the hull or the upper ends of the 'long arms' of floor timbers (**Figure 3.21**).[305]

[302] McCarthy 2005, 68.
[303] For an ancient reference to the lubrication of treenails and pegs with pitch or other substances before driving, see Casson's interpretation (1995, 205-6, n. 22) of a passage from Plutarch's *Moralia* (*Mor.* 321d 10.22); see also Coates 2001, 159; McCarthy 2005, 67.
[304] Treenails in post-medieval European shipbuilding were typically made of the same diameter or a slightly larger diameter than the hole into which they were driven; this difference in diameter was called the 'drift' (McCarthy 2005, 67).
[305] Pegged or wedged treenails were found only on a few frames, including TN 36 of FL 25, near the end of its upper 'long arm'; in TN 2 of FL 18, which fastened the floor to PS 13/Wale 1; in UM 3 (a probable end of the 'long arm' of a floor); and single treenails in UM 15 and UM 21, both futtocks or top timbers. These treenails were wedged on their inboard ends. It is possible that some treenail wedges were missed during the sampling of over 500 treenails in the planking for wood identification and the inability to examine the outer face ends of many of the treenails in the planking. The treenails were clearly driven from outside of the hull based on their tapering diameter. However, wedged or spiked treenails were not found among the significant number of treenails whose outboard ends were examined. Many of the treenails on the Serçe Limanı shipwreck were wedged with wooden wedges or iron nails (Bass et al. 2004, 98). The use of wedged or pegged treenails was also a common practice in post-medieval wooden

Figure 3.21: A wedged treenail used to fasten FL 25 to the wale (PS 13). The occurrence of wedged or spiked treenails is very unusual in YK 14's hull; their use seems to be restricted to the area of the waterline or above.

3) Timber Catalog: Keel Timbers

Three separate, intact keel timbers survived in the hull (**Figures 3.22-4; Table 3.2**). Keel 2, the main keel timber and the first timber to be laid during the construction of the vessel, is 6.55 m in length and formed the backbone of the ship between floors FL 11 and FL 37. Keel 3, a 3.45 m-long curved keel timber, formed the bow section of the keel between FL 37 and FL 51 as well as the transitional piece between Keel 2 and the stem, which did not survive. Keel 1, the smallest keel timber, located between floors FL 3 and 11, is 1.96 m long and formed the transitional piece between Keel 2 and the sternpost.

shipbuilding into the twentieth century, although the size of the timbers involved was much larger (see McCarthy 2005, 67-8, Fig. 40).

All three keel timbers are structurally solid and have well-preserved surface features in most areas. The poorest surface preservation occurs on the exposed forward-scarf extremity of Keel 3; this area suffered some damage from abrasion during or after the wrecking of the ship and had slightly softer surfaces than the other parts of the keel. The aft scarf of Keel 1 also suffered damage during the wrecking of the ship: a piece of the inner face of Keel 1 just forward of the hook scarf, as well as a section of the port side of the scarf, were broken off when the sternpost was wrenched out during the shipwreck. The inner-face fragment, as well as the original scarf key for the Keel 1/sternpost scarf, were discovered during the excavation and secured with stainless-steel wire in their original positions. Part of the forward hook scarf of Keel 1 was split off in the Keel 1/ Keel 2 scarf, possibly due to hogging of the hull before or during the shipwreck; these pieces were also wired into place. Keel 2 is in excellent condition aside from a crack at the transverse hole in the keel between FL 28 and 29, and a slight hog in the timber, which must have occurred during the ship's period of use. Keel 3 shows no sign of hogging or other distortion in its shape, but a transverse crack or split exits its aft end; this damage must have occurred before the excavation of the ship, probably when the ship was sinking.

Table 3.2: Basic Dimensions of the Keel Timbers

Keel Timber:	Length (m):	Molded-Dimension Range (cm):	Sided-Dimension Range (cm):	Scarf Lengths (Forward, Aft Scarf, including Mortises) (cm):
Keel 1	1.96	11.55-12.25	7.35-10.45	19.2 / 22.8
Keel 2	6.55	11.2-16.5	9.05-12.45	22.7 / 26.4
Keel 3	3.45	12.1-15.4	7.5-11.0	28.4 / 21.55
Sternpost Fragment	0.039	2.85	1.55	-

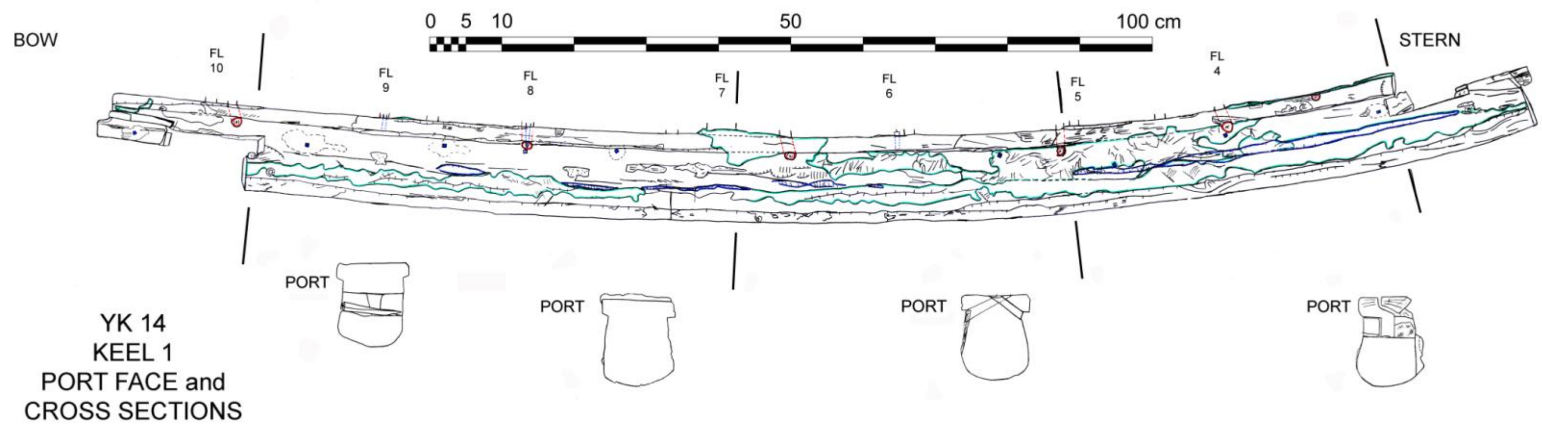

Figure 3.22: Keel 1, port face and cross sections.

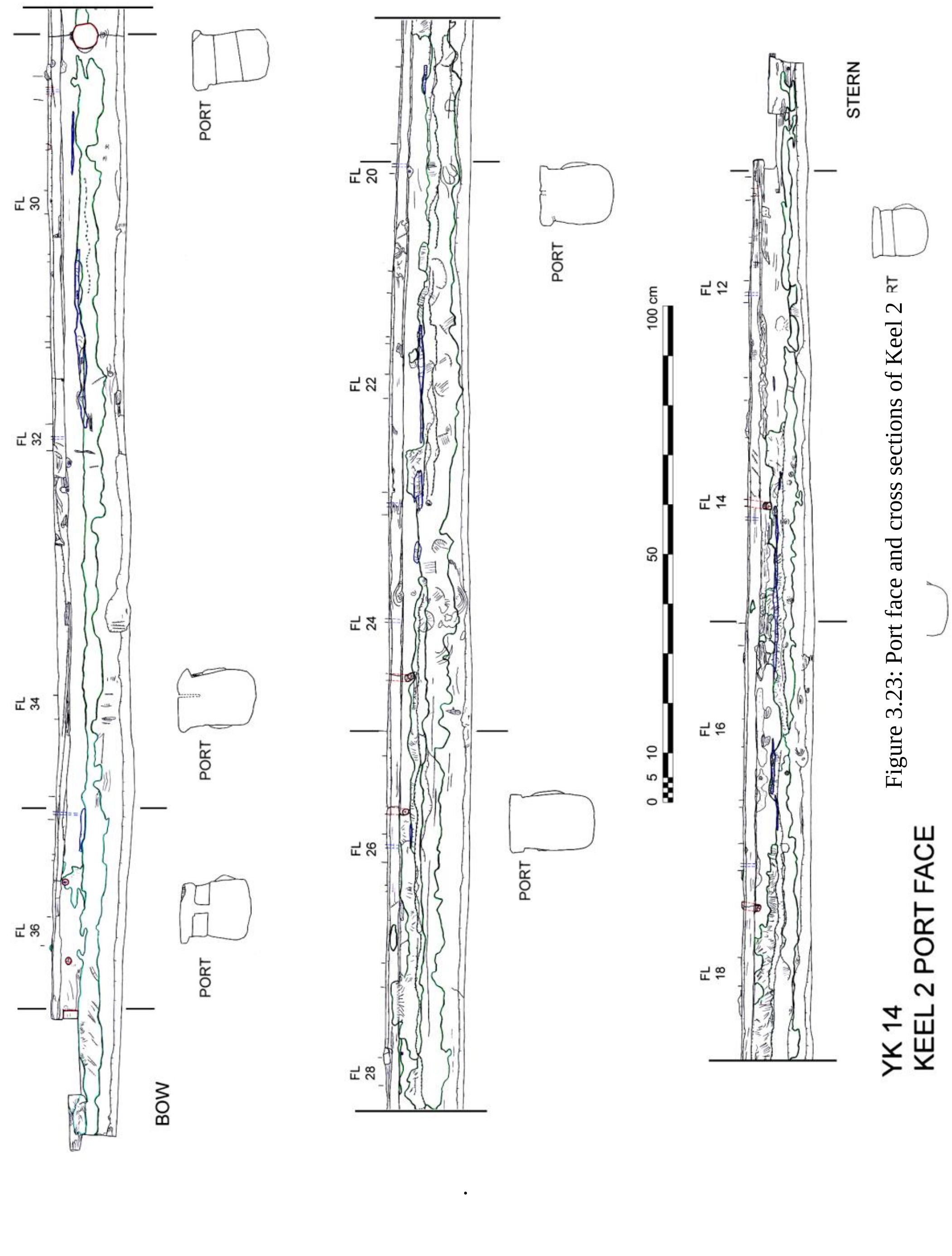

Figure 3.23: Port face and cross sections of Keel 2

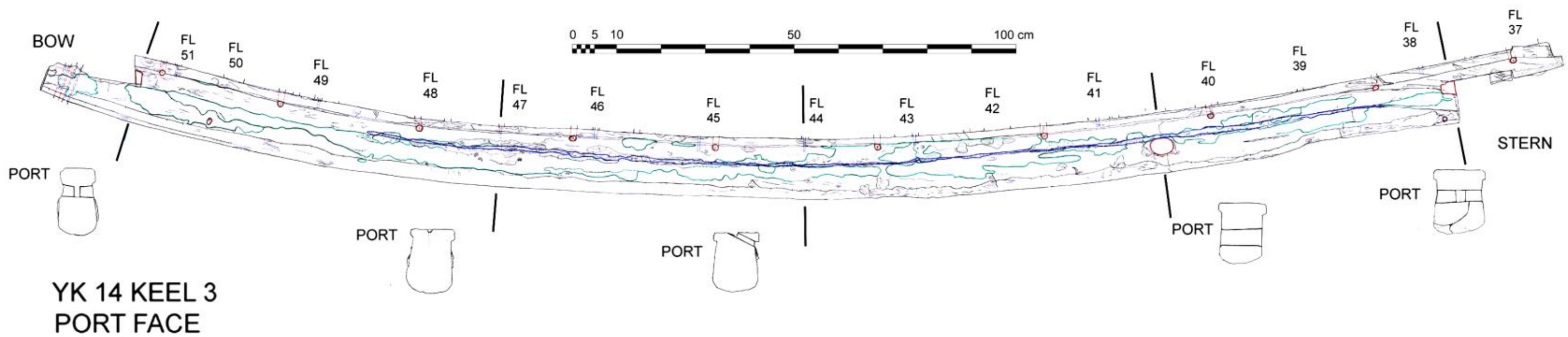

Figure 3.24: Port face and cross sections of Keel 3.

Combined, the three keel timbers are approximately 11.42 m in length. All three timbers were cut from logs of Turkey oak (*Quercus cerris*), as were the scarf keys used in the locking of joints between the timbers. The pith of the tree is visible on the scarf ends of each of the keel timbers: on the cross section of Keel 1, approximately 30 rings are evident, while approximately 20-30 rings are visible on the ends of Keel 2, and approximately 25-30 rings are found on the ends of Keel 3. The initial shaping of the logs may have been done with a combination of sawing and hewing with axes, but any trace of this work was removed by later adze-work on the timbers.

The ends of the ship, including the stem and stern, are missing, but part of the approximate curvature of the sternpost aft of Keel 1 was preserved by the intact hood ends of strakes 2 and 3 on both the port and starboard sides. Both the forward end of Keel 1 and the aft end of Keel 3 terminate with a keyed-hook scarf very similar to those connecting the Keel 1 and 2 and Keel 2 and 3 timbers. In the port-side mortise of Keel 1's aft scarf, a tenon from the original sternpost's hook-scarf end was preserved. The fragment measured 3.9 cm in length and has a roughly rectangular cross section (2.85 cm molded, 1.55 cm sided) (**Figure 3.25**). Similar to the other keel timbers, the sternpost was made from Turkey oak (*Q. cerris*). The hood ends for the garboard and those of the next few strakes join Keel 1 at a much steeper angle than on the opposite end of the hull, at the forward end of Keel 3. These features, as well as the greater width of the hull at Keel 3, indicate that Keel 1's location corresponds to the stern area of the ship.[306]

[306] C. Pulak, personal communication.

Figure 3.25: Sternpost fragment in Keel 1's aft scarf.

Most of the outer faces of the keel timbers are rounded and smooth, although some bevel cuts are still visible along the forward scarf end of Keel 3 (**Figure 3.26**). This smoothness seems to be due in large part to wear, but it also appears that in most areas of this face only the outer bark was removed from the keel timbers. No fastener holes or other evidence of a false keel were found on their outer faces. An area of more pronounced wear occurs in an approximately 40 cm-long section on the outer face of Keel 3 towards its aft end (FL 37-39 area) (**Figure 3.27-8**). Here, large portions of the original surface are missing; this damage is likely due to wear from beaching the vessel. Such damage was not observed on the other keel timbers.

Figure 3.26: A section of the outer face of Keel 2, showing surface wear.

Figure 3.27: Worn area on the outer face of Keel 3 corresponding to the locations of floors FL 38-40.

Figure 3.28: Detail of the worn area on the outer face of Keel 3, possibly caused by frequent beaching or grounding.

Rabbets were cut along the port and starboard faces of all three keel timbers with an adze or chisel, giving each a roughly ‘T’-shaped cross section. The rabbets are quite uniform across the length of all three timbers, ranging in depth from 0.5 to 1.65 cm, and were on average about 1.0 cm deep. They were generally cut 2.0-2.5 cm below the inner face edge of the keel timbers, although there was some variation. Based on other Yenikapı ships, it the rabbets probably continued only on the lower parts of the endposts.[307] The average sided dimension of the keel timbers is 11.2 cm; the keel timbers have a clear taper from amidships to FL 3, with the smallest sided dimension occurring around FL 4 (9.1 cm). The sided dimension also tapers towards the bow, where it becomes 9.25-10.5 cm toward the forward end of Keel 3. The smaller dimension of the keel timbers toward the southern end of the shipwreck also seems to indicate that this end is the stern end of the vessel. The average molded dimension of the keel timbers is 14.4 cm. These dimensions of the keel timbers also show a marked taper, with the largest occurring towards the center of the ship in the area of FL 25-26 (16.5-16.8 cm), with a slight decrease towards the forward end of Keel 3, and a much larger decrease occurring towards the forward end of Keel 1.

Tool Marks and Surface Features

Aside from the scarf ends, the preserved surfaces on the keel timbers were shaped entirely by adzing. Tool marks are well preserved on all three of the keel timbers on the port and starboard faces, particularly in areas where the timber's surfaces were protected by a layer of pitch or caulking. Surface features are slightly less well preserved on the more exposed inner face of Keel 2, but were protected by a thick layer of pitch on much of the inner faces of Keel 1 and Keel 3. On Keel 3, generally, the tool marks are better preserved on the starboard rather than the port (Keel/SS1 seam) face of the timber since

[307] On the galley YK 4, the main keel timber had very similar rabbets to those on YK 14's keel, but these rabbets ended on an endpost recovered from the wreck site. A section of one endpost was also recovered from YK 5, but neither the endpost nor the other two recovered keel timbers were rabbeted.

this was the least exposed area of the timber; the garboards along the forward half of the Keel/SS 1 plank seam had been wrenched out of place during the ship's sinking. The worst surface preservation occurs on the port face of Keel 3, near the forward end scarf, which was fully exposed during the wrecking of the ship (**Figure 3.29**).

Figure 3.29: Forward scarf of Keel 3 during the excavation; note the wear around the scarf end and the rabbet.

Frames FL 12, 14, and 20 were installed in the hull into adzed depressions on Keel 2's inner face, the depression at FL 20 being particularly deep (**Figure 3.30-1**). All three of these floor timbers were nailed to the keel. These depressions were probably cut after the lower planking was assembled and the floor timbers were being shaped to fit flush against the inner face of the keel timber; similar adzed depressions were found on some hull planks at frame locations as well. No score marks were found on the inner faces of the keel timbers to indicate frame locations or locations of edge fastener, with the possible exception of a mark at the forward edge of FL 45 (**Figure 3.32**).[308] Other marks may have been scored on the keel during construction but were later obliterated by adzing.

Figure 3.30: Adzed depression cut into the inner face of Keel 2 at the location of floor FL 20.

[308] Such score marks were found on the inner faces of the tenth-century YK 5 and YK 24 ships, but neither ship had a rabbeted keel.

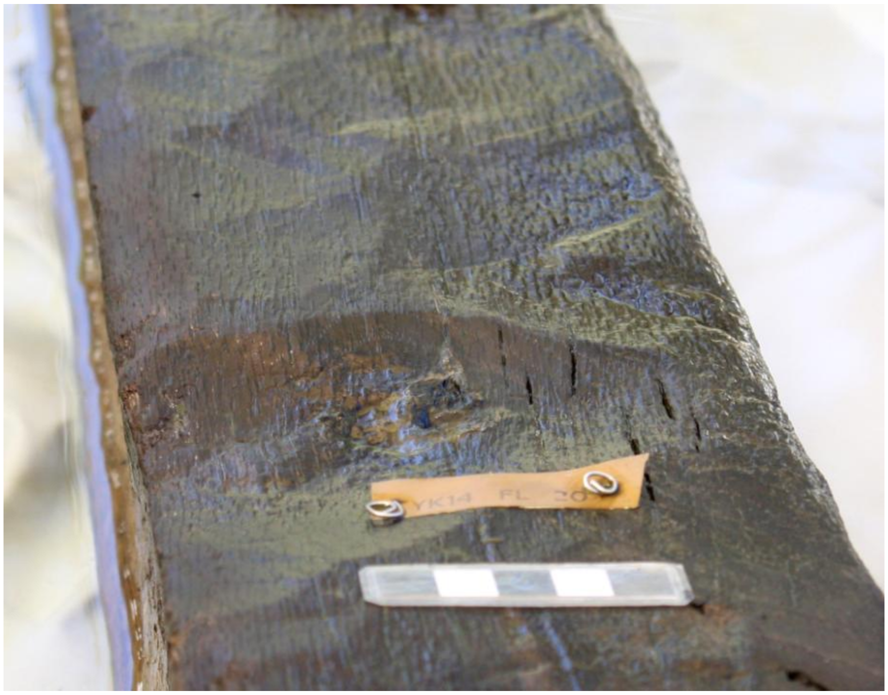

Figure 3.31: Adzed depression in Keel 2's inner face at the location of FL 20.

Figure 3.32: Possible score mark on the inner face of Keel 3, at the forward edge of the location of floor FL 45.

The Scarf Ends of the Keel Timbers

All of the keel-scarf ends, including scarf ends connecting the keel timbers to the now-missing endposts, were fastened with hook scarfs wedged with wooden keys. The vertical cuts at the scarf ends were made with a saw to the desired depth in the wood, after which the scarf ends were carefully finished with a chisel. The scarf between Keel 2 and Keel 3 is a perfectly preserved example of the type of hook scarf used for the scarf joints in the keel and endposts. This scarf occurs between FL 37 and 38, is approximately 26 cm long, and was secured with a single wooden scarf key with a rectangular cross section. The edges of the scarf were heavily caulked in comparison to other plank seams in the hull in order to prevent leaks around the joint. The caulking ranges in thickness from 0.7 to 1.7 cm and may have been applied during the initial construction of the ship or perhaps during a later maintenance episode (**Figures 3.33-5**).[309] No other fasteners were used to secure the scarf. A wooden chock or scrap piece was found wedged into the starboard side of the forward end of Keel 3, where part of the rabbet had been broken or cut off; its function, if any, is unclear.

[309] Caulking in other plank seams with no obvious signs of repairs tends to be 0.1-0.5 cm thick. A transverse crack in Keel 3, which begins at the scarf, may also have been a source of leakage and caulked with this material.

Figure 3.33: Heavy caulking discovered around the Keel 2/ Keel 3 keyed-hook scarf after removing the port garboard strake**.**

Figure 3.34: The port face of the Keel 2/Keel 3 hook scarf with most of the caulking removed. Note the scarf key.

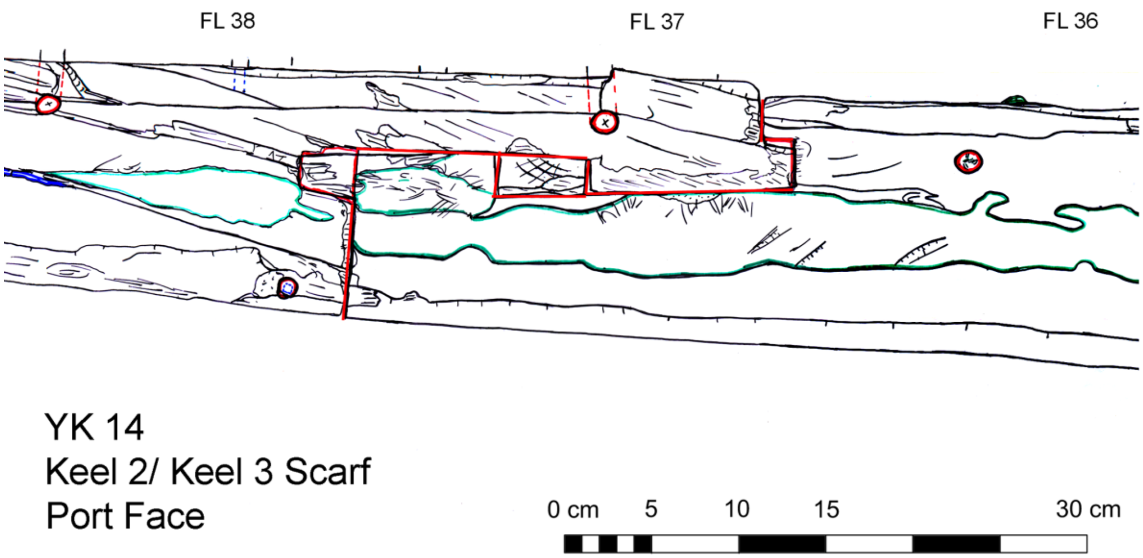

Figure 3.35: The Keel 2/Keel 3 keyed-hooked scarf.

The 21.6 cm-long forward scarf of Keel 3, although damaged, is similar to that on the opposite end of the timber; however, additional fasteners were used on this scarf (**Figures 3.36-7**).

Figure 3.36: The forward scarf end of Keel 3. Note the concretion from the iron fastener driven in the forward end of the scarf.

Figure 3.37: The fastener holes in Keel 3’s forward scarf seen from above, after removing most of the iron concretion around the fastener holes.

Two pilot holes, 1.3-1.4 cm in diameter, were found containing iron nail or spike concretions, along with caulking material, in the forward of the two holes. The aft and larger hole contained an iron fastener shank with a maximum cross section of 1.3 x 1.2 cm, while the fastener shank in the forward hole is 0.5 cm squared on its outer face end, revealed after the caulking fibers were removed. The lengths of these nails were slightly longer than those of other nails used in the hull; they would have been at least 14.0 to 14.5 cm long if they only secured the scarf end, and 20 cm or longer if they were also driven through a floor timber or were clenched over a floor or endpost timber. No evidence of clenching or of a nail head were found on the outer face of the keel timber. However, the area around the aft fastener, which is approximately 3.5 cm in diameter, is less worn than the surrounding wood, indicating that it was covered by the head of an iron fastener, perhaps a bolt head based on the large diameter (**Figure 3.38**).

Figure 3.38: Pilot holes for fasteners in the outer face of Keel 3 at the timber's forward scarf. Note raised area around the head of a bolt or spike at right; the fastener's head seems to have protected the wood from wear. The hole on the left was filled with caulking on its outboard end, and contained a nail concretion on its inboard end, possibly from a floor timber.

A concave depression, approximately 3.0 cm in diameter and 0.5-1.0 cm deep, was found in the concretion when it was removed, but it was unclear whether it was a poorly-preserved mold of the fastener's head or, more likely, a bleed from the iron concretion. The aft fastener was likely a large clenched nail or bolt used to fasten the scarf. The forward fastener's function is less clear. The diameter of the nail shank is accessible only on the interior end of the scarf, while the outboard end of the pilot hole was packed with caulking. Its use as a fastening a floor timber is possible, in which case it represents frame floor or futtock 52; the fastener hole is aligned with a drilled hole in plank PS 6-3 as well. Other possibilities include an abandoned fastener hole or broken nail, a temporary keel scarf fastener used during construction that was later supplemented with an iron spike or bolt, or a later repair fastener. The pilot hole, which runs through the thickness of Keel 3 at this point, makes the identifying the function of the hole more difficult. The fastener would necessarily be a clenched nail or bolt to have any structural function, since the fastener's shaft was not in contact with the wood due to the pilot hole and could therefore not have functioned as an effective fastener through friction alone.

The 21.1 cm-long Keel 1/sternpost scarf at the aft end of Keel 1 is similar to the Keel 3 scarf end in the bow. A rectangular piece of wood was found in the bilge just behind the scarf (**Figure 3.39-40**). Because its length is the same as the sided dimension of the keel at the after end of the hull, this wood piece is almost certainly the scarf key for the joint. No other fasteners were used to secure the scarf end. A 0.3-0.4 cm-thick caulking deposit found in the port mortise of the forward end of the scarf, indicated that the scarf tenon from the missing sternpost timber was not a tight fit on this side for the mortise in Keel 1.

Figure 3.39: The aft scarf of Keel 1 after excavation. The scarf key and a piece of the scarf were found loose.

Figure 3.40: The aft scarf of Keel 1, with loose wood fragments and scarf key secured in their original locations.

The 23-cm-long hook scarf between Keel 1 and Keel 2 was originally designed to resemble the other scarf joints on the keel. However, it was modified during construction, perhaps due to a mistake in cutting the scarf: the shipwright cut out the central tenon section on the Keel 2 side of the scarf dividing the two scarf mortises, and instead secured the scarf with three separate scarf keys (**Figures 3.41-8, Table 3.3**). The area around the scarf was heavily caulked, with deposits ranging in thickness from 0.5 to 1.2 cm. A 0.8 to 1.3 cm-wide gap on the upper face of the scarf between the inner faces of Keel 1 and 2 was also filled with pitch and caulking (**Figure 3.41-2**). While cleaning out the scarf in preparation for separating the keel timbers, caulking fibers were found in the scarf mortises and were driven horizontally around the scarf table to a depth of at least 3.5 cm. In spite of these precautions, the extra waterproofing materials and the hogging in this section of the keel timbers suggest that this area leaked more than the other scarfs and needed additional maintenance.[310] Despite this, working with the inferior scarf joint on Keel 2 was probably considered a better option than re-cutting the joint and substantially shortening either keel timber.

Table 3.3: Scarf Key Dimensions

Scarf Key:	Length (cm):	Cross Section—Port Side (cm):	Cross Section—Starboard Side (cm):	Notes:
Keel 1/Sternpost	7.25	1.85 x 1.0	2.2 x 1.6	Probable scarf key found in bilge just forward of the scarf end
Keel 1/2—Forward Scarf Key	8.2	1.1 x 0.75	1.75 x 0.8	Irregular cross sections on both sides—crudely cut or split from a larger piece of wood. Port end damaged during dismantling of hull
Keel 1/2—Middle Scarf Key	5.8	1.85 x 0.75	1.3 x 0.55	Short key, does not reach port face of keel
Keel 1/2—Aft Scarf Key	9.0	2.15 x 1.15	1.75 x 0.75	
Keel 2/3 Scarf Key	11.3	4.9 x 2.3	4.7 x 1.8	Slightly damaged on port face during dismantling of hull

[310] Just forward of the scarf, in the FL 11-12 area, caulking deposits along the Keel/SS 1 seam appeared to have two distinct layers—an outer, more fibrous layer of caulking, and a more solid inner layer along the keel timber—an indication that the scarf area was likely re-caulked.

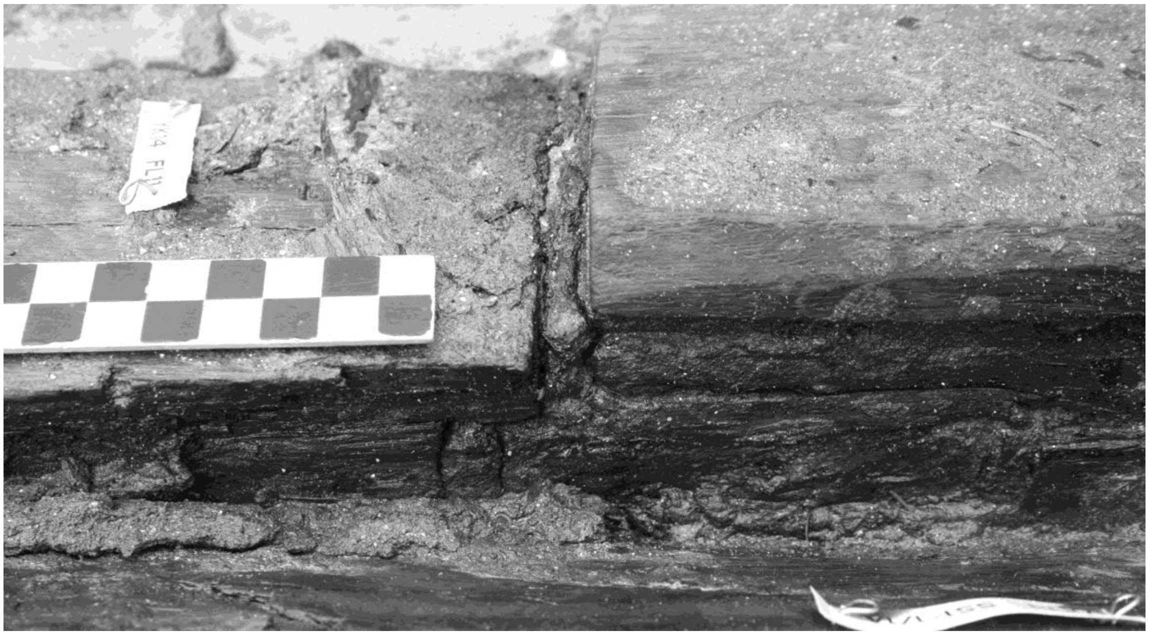

Figure 3.41: Pitch in the gap between the inner faces of Keel 1 and 2.

Figure 3.42: Thick pitch and caulking on the port face of the Keel 1/2 scarf.

Figure 3.43: The Keel 1/ Keel 2 scarf, with the forward key partly removed.

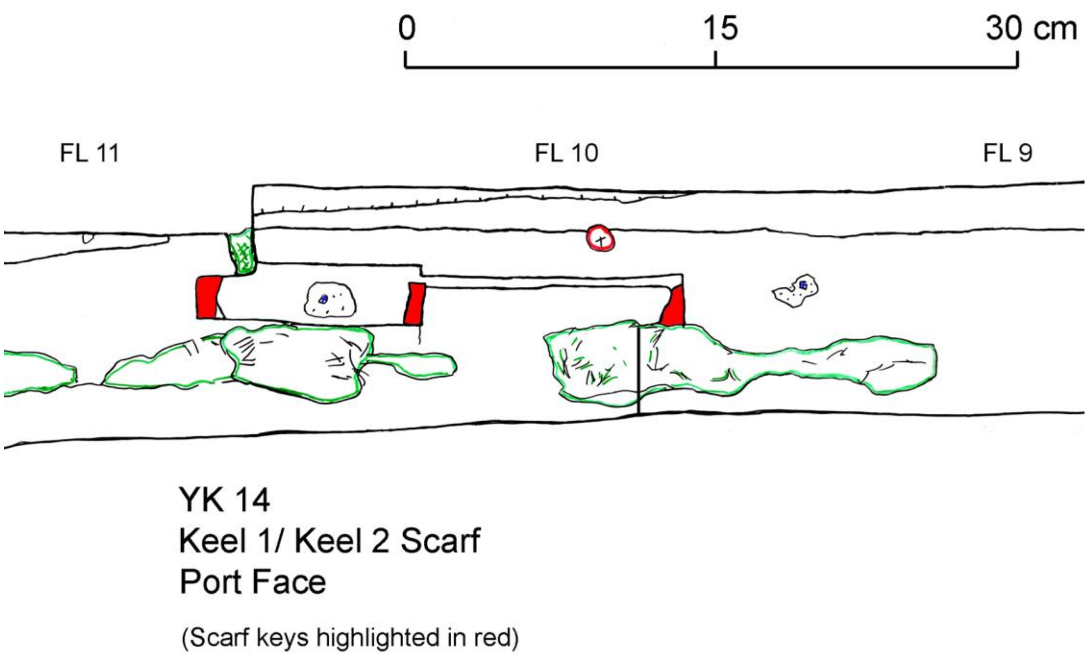

Figure 3.44: The Keel 1/Keel 2 scarf, port face view.


Figure 3.45: The broken section of the Keel 2 scarf. The split was found full of sand, and appears to have broken in antiquity.


Figure 3.46: The aft scarf of Keel 2 after the removing the garboards and Keel 1 timber. Note the thick caulking and heavy pitch deposits on the keel/SS1 plank seam.


Figure 3.47: View of the middle scarf key in the Keel 1/Keel 2 scarf in situ, after the removal of Keel 1.

Figure 3.48: The middle scarf key of the Keel 1/Keel 2 hook scarf in situ.

Part of the forward scarf of Keel 1 was broken in antiquity, either before or, more likely, during the sinking of the ship (since there is no indication of caulking or repairing the split): the split was found filled with sand, indicating that it was an old break. The Keel 2 scarf end was also somewhat compressed by hogging, which seems to have affected the aft section of Keel 2 overall (**Figure 3.49**). This may have caused or contributed to the break in Keel 1.

Figure 3.49: Port face of Keel 2's port face during excavation, after removing the frames and strakes SS 1 through SS 7. Note the slight hogging in the shape of the keel.

Transverse Holes in the Keel Timbers

Two transverse holes were cut through the port and starboard faces of the keel timbers below the garboard strakes. The aft hole was cut through Keel 2 between FL 28 and 29 and measures 4.6 to 4.8 cm in diameter on its starboard face and 5.0 to 5.2 cm in diameter on its port side (**Figures 3.50-1**). A second transverse hole was cut through Keel 3 between FL 40 and 41, measuring 4.9 x 4.0 cm in diameter on the starboard (Keel/PS1) side and 5.2 x 3.7 cm on the port (Keel/SS1) side of the timber (**Figures 3.52-3**). Both holes are worn around their forward edges; at the aft hole in Keel 2, this area of wear is approximately 1.3 cm wide on the port side and 2.0 cm wide on the starboard side, while on the forward hole on Keel 3 it is approximately 2.1 cm on the port and starboard sides. The insides of both holes are worn smooth, and no tool marks survive, but they were likely made by a combination of drilling and chiseling.

Figure 3.50: The central transverse hole in Keel 2, shown after the removal of strakes SS 1-SS 7.

Figure 3.51: Port face view of the hole in Keel 2 between FL 29-30. Note the wear to the left (forward) side of the hole**.**

Figure 3.52: The forward transverse hole in Keel 3, between FL 40-41.

Figure 3.53: Detail of the transverse hole in Keel 3. The detail view shows the starboard face of the hole: the forward end is to the right**.**

The reason for these holes is unclear, but they were most likely cut for running cables through the keel to assist in towing or beaching the vessel. Similar transverse holes have been found on the keel and endpost timbers on many of the shipwrecks at Yenikapı.[311] The Saint-Gervais 2 shipwreck, dating to the mid-seventh century C.E., also had a

[311] These include three of the other Yenikapı shipwrecks under study by the Institute of Nautical Archaeology dating from the eighth to later tenth centuries: YK 1, (two holes), YK 23 (single hole), and YK 24 (single hole). This feature was also recorded on shipwrecks from Yenikapı documented by Istanbul University, including YK 6, 7, and 15 (each with one hole in the keel), and YK 8, 9 and 12 (each with two holes in the keel and/or endpost timbers), dating from the eighth to eleventh centuries (Özsait-Kocabaş and Kocabaş 2008, 102-4, 114, 117, 125-26, 132-36, 148, 164, 166).

similar transverse hole with rope fibers found inside it.[312] Although cutting holes in the keels of these vessels potentially introduces a structural weakness, it seems that their presence was sufficiently important for them to be included. Since the keel timbers are by far the most robust timbers in YK 14's rather lightly-built hull, they are probably the best timbers to attach ropes for towing or beaching the vessel.[313]

Pitch and Caulking on the Keel Timbers and the Keel/Garboard Plank Seam

The section of the keel timbers exposed on the exterior of the hull was heavily pitched along the port and starboard faces; in many areas, the pitch was up to 0.7-2.5 cm thick, with the thickest deposits occurring around the keel/garboard seam. These deposits, along with the locations of edge fasteners for the keel/garboard seams, delineated the general location of the bearding line along the length of the keel. The original location of the garboard strakes is visible above this pitch deposit, often clearly marked by caulking fibers (**Figure 3.54**). Along most of the length of the keel, the caulking was about 0.4-0.7 cm thick at the seam, with pitch deposits of 0.5-1.5 cm thick built up on the exterior of the hull at the location of the seam. The keel caulking is generally thicker than that in the seams of original hull planking that had not been replaced.

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[312] Jézégou (1992, 31) records a transverse hole 4.5 cm in diameter in the keel of St. Gervais 2 approximately 10 cm from the lower face of the keel, with a piece of rope found inside it. This feature appears to be uncommon on ships of this period found outside of the Yenikapı site, although it must be kept in mind that features of keel timbers are difficult to examine if a shipwreck has not been fully excavated and dismantled, or measures are taken during the excavation to examine the sides of the keel. With the St. Gervais 2 wreck, the excavators dug under the wreck to examine one face of the keel (Jézégou 1992, 32).

[313] C. Pulak, personal communication.

Figure 3.54: Detail view of a keel/garboard seam caulking on the port face of Keel 2. Note the barnacle to the lower left.

At a few locations on the keel/garboard seam that were probably re-caulked, deposits of up to 2.0 cm thick were removed.[314] Barnacles 0.7 to 1.4 cm in diameter were found in the pitch layer on the port and starboard faces of the keel, some partly obscured by pitch; possibly these shells were covered in later applications of pitch during hull maintenance episodes.[315] Rough grooves or gouges were found on the port and starboard faces of the keel in the area of the keel/garboard seam, underneath thick caulking and pitch deposits in most areas (**Figures 3.55-6**). These measured 0.4 to 1.3 cm wide and were generally 0.1 to 0.4 cm deep; they were filled with pitch, and grass fibers were found to be driven deep into the cuts in many areas. These grooves or gouges were probably caused by caulking irons, either during the initial construction of the ship or, more likely, during a later episode of re-caulking or maintenance of the hull. In most areas, the grooves were concealed under caulking and pitch, and wood splinters protruding from the hull were embedded in the pitch. These grooves were found on both faces at the locations described in Table 3.4.

[314] A caulk deposit 1.5 cm thick was found on the Keel 1/PS 1-1 seam between FL 5-6, containing a broken coak. It had somehow been driven through the garboard strake's keel edge but had missed the hole drilled for it in the keel, and was wedged in the keel/garboard seam. This likely was a source of leakage, which was repaired with more caulking, apparently without the removal of the previous caulking deposits.

[315] Similar barnacles were sometimes found on the outer faces of the hull planks as well; these were 0.6 - 1.45 cm in diameter, with the largest observed on the outer faces of garboard planks. Steffy also noted evidence for multiple pitching episodes on the Kyrenia and Serçe Limanı shipwrecks based on differences in the color of the pitch deposits; in the latter case, a pitch/grass caulking combination was used (Steffy 1999, 402-3). The size of these barnacle shells could perhaps be used as a rough indication of the length of time between applications of pitch to the hull.

Table 3.4: Possible Caulking Iron Damage on Keel Timbers

Keel Timber:	Damage Locations (approximate, based on frame locations), Port Face:	Damage Locations (approximate, based on frame locations), Starboard Face:	Notes:
Keel 1	FL 5 area from FL 6-FL 8 Between FL 8-9	From between FL 6-7 to FL 9	Damage on Keel 1 most pronounced on the port face in the FL 5 area
Keel 2	At FL 13 Between FL 14-15 Between FL 16-17 At FL 19 Between FL 21-22 Between FL 23-24 At FL 26 Between FL 29-30 Between FL 30-31 At FL 32 At FL 35	Between FL 33-34 Between FL 36-37	
Keel 3	Between FL 38-39 FL 39-40 Between FL 40-41 to FL 42 From between FL 43-44 to FL 45 From between FL 46- to FL 47 location Between FL 48-49	Continuous grooves/gouges from between FL 38-39 to between FL 48-49	

Figure 3.55: A roughly-chiseled groove was found on the port face of Keel 3 under the caulking and pitch layer. The groove is at the approximate location of the bearding line, and was found full of caulking and pitch; this damage was likely caused by re-caulking of the keel/garboard seam.

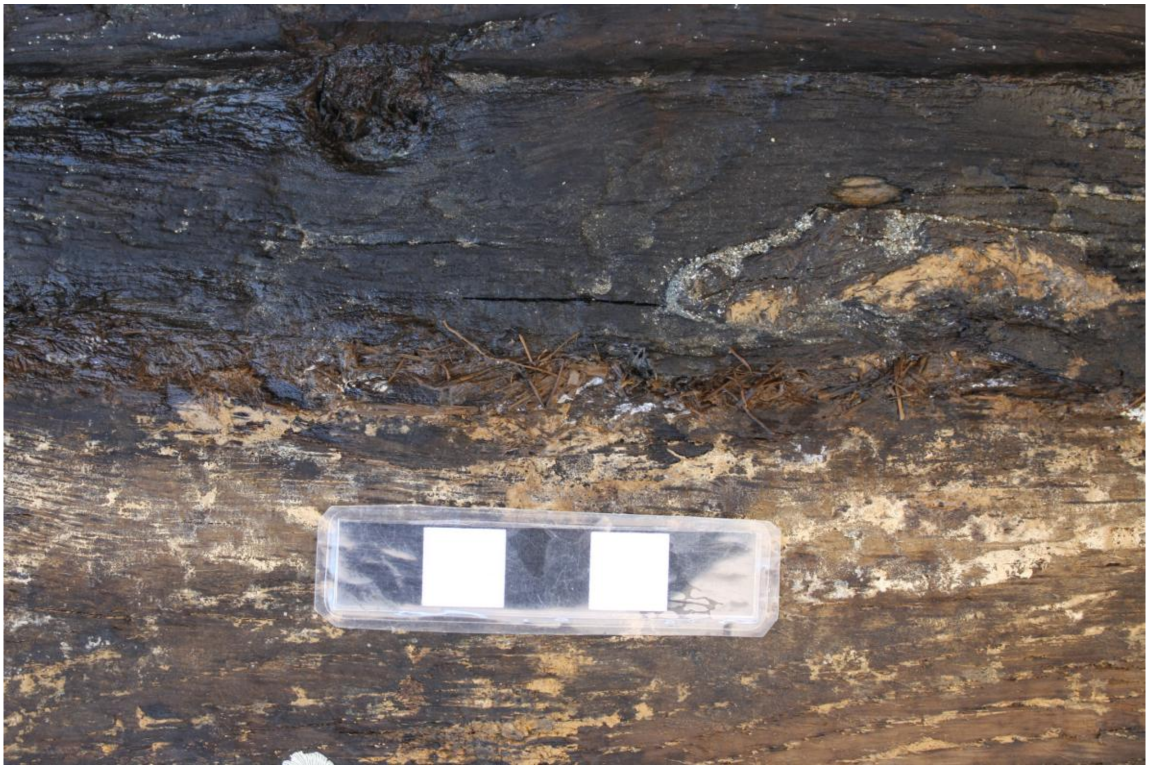

Figure 3.56: Detail of one of the gouged areas in the keel; Keel 3, port face (Keel/SS 1 plank seam). Note the caulking fibers forced into the gouged depression.

Pitch was also heavily applied to the keel/garboard plank seams inside the hull, in the gap above the keel rabbets and the inner faces of the garboard strakes (**Figure 3.57**). These deposits ranged in width from 1 to 3 cm, although in some areas under floors they filled larger gaps, from 0.3 to 1.7 cm in depth. Judging from the thick pitch deposits applied to the keel/garboard seams inside the hull, these deposits have two possible causes. During the application of pitch inside the hull, it may have flowed into the keel/garboard seam, the lowest point in the hull. Because this area was also a potential source of leakage, the thickness of the pitch deposits could have also been deliberate.

Figure 3.57: Pitch ridge on the aft scarf of garboard plank SS 1-2.

Keel Fasteners

Several types of fasteners were used on the keel timbers. On the port and starboard faces, the garboard strakes were edge-fastened to the keel with regularly-spaced, angled wooden coaks driven into the keel rabbet and supplemented by iron nails in some areas. These fasteners will be discussed in more detail in the following section on hull planking.

In addition to the coaks connecting the keel and garboard strakes, three fastener holes below the garboard strakes were found in the keel timbers. A drilled hole 1.2 cm in diameter and approximately 1-2 cm deep was found in Keel 3's port face in the area of FL 50, just above the beginning of the outer face bevel; the hole was found filled with pitch and caulking (**Figure 3.58**). A second drilled hole was found on the port side, just above the outer face bevel, below the location of FL 38, on the opposite end of Keel 3. The hole is 1.1 cm in diameter and contains a nail concretion 0.6 cm square in cross section and up to 7.2 cm long (**Figure 3.59**). Both fastener holes are possible evidence for temporary attachments of stocks or braces to the keel timbers during construction.

Props or supports of this type may have been particularly important for immobilizing the Keel 3 timber, due to its pronounced curvature.

Figure 3.58: Drilled hole in the port face of Keel 3, in the approximate location of floor FL 50 (next to scale), below the garboard's original position.

Figure 3.59: Keel 3's aft scarf, port face view. Note the nail hole near the outer face edge just aft of the beginning of the scarf (FL 37-38 area).

On Keel 2, a third drilled hole 1.5 cm in diameter and 2.6 cm deep was found in the port face in the area of FL 36-37, slightly below the original location of the garboard strake. The hole was filled with pitch and caulking, so it could not have been used to accommodate a fastener when the ship sank. It may have been from a third fastener for stocks or props, and had been pitched over during construction, or an unused fastener originally intended for a keel/garboard seam fastener. Two more drilled holes were found under caulking in the keel/garboard seam areas on the Keel 1 timber; these are most likely unused holes for garboard edge fasteners.

Frames Attached to the Keel Timbers

Eighteen of the 45 extant floor timbers were nailed to the inner faces of the keel timbers.[316] Based on fastener holes in the hull planking, an additional five to seven floor timbers were inserted in the hull at either end of the ship, one to three of which were fastened to keel timbers.[317] The frames were spaced approximately 14.4 to 25.4 cm apart (center to center), but aside from a few frames at either end of the ship, nearly all of the frames were spaced approximately 21 to 24 cm apart, with an average spacing of 22.9 cm (**Table 3.5**). Floor timbers that were nailed to the keel were spaced 20.4 to 76.7 cm apart, with an average spacing of 49.0 cm. The positioning of the floors, although not corresponding to a particularly exact measuring standard, nonetheless could have been roughly based on a handspan measurement used in the Byzantine period of

[316] Floors FL 6, 9, 11, 12, 14, 17, 20, 23, 24, 26, 29, 32, 35, 38, 41, 43, 46, and 47 were fastened to Keel 1, 2, and 3.

[317] Up to two or three floors aft of FL 4, the after-most surviving floor on Keel 1, may have also been fastened to the sternpost, which did not survive. Fasteners in the hull planks at the ends of the hull indicate that there were at least two or three additional floors at the stern end and at least four at the forward end.

approximately 23.4 cm.[318] Many of the nail holes for frame fasteners in the inner face of the keel were located in shallow, predrilled pilot holes. Floor timbers at locations with these features were probably positioned in the hull before the drilling of the pilot holes. Each hole was probably drilled through the thickness of the floor timber until the drill began to penetrate the keel's inner face; then, a keel nails could then be driven through the pilot hole to fasten the floor timber to the keel.

Table 3.5: Floor Fasteners in the Keel Timbers and Room and Space Measurements of the Floors

Floor Loc.:	Fast-ener Type:	Fastener's Cross-Sectional Dimensions (cm):	Pilot Hole? (Y/N; diam/ depth) (cm):	Min. Fastener Hole Depth (cm):	Distance to Previous Frame (Center to Center) (cm):	Distance to Previous Keel Nail (Center to Center) (cm):	Notes:
FL 1	-	-	-	-	-	-	Fasteners on PS 3-1, SS 3-1 only
FL 2	-	-	-	-	21.5 (approx.)	-	Fasteners on planking only; keel/endpost does not survive
FL 3	-	-	-	-	21.4 (approx.)	-	Fasteners on planking only; keel/endpost does not survive
KEEL 1:							
FL 4	-	-	-	-	24.5	-	
FL 5	-	-	-	-	21.1	-	
FL 6	Nail	0.65 x 0.6	N	3.05	24.5	-	
FL 7	-	-	-	-	22.7	-	

[318] The Byzantine handspan measurement roughly corresponds to the distance between the tip of the thumb and the tip of the little finger on an individual's splayed hand, or 12 *dactyloi* (Schilbach 1970, 19). For example, if the master builder was using his own hand to measure a handspan, there would likely be some deviation based on how widely he spread his fingers (Harpster 2005a, 486).

Table 3.5. Continued

Floor Loc.:	Fast-ener Type:	Fastener's Cross-Sectional Dimensions (cm):	Pilot Hole? (Y/N; diam/ depth) (cm):	Min. Fastener Hole Depth (cm):	Distance to Previous Frame (Center to Center) (cm):	Distance to Previous Keel Nail (Center to Center) (cm):	Notes:
FL 8	Nail (rep-air)	0.55 x 0.55	N	3.8	24.0	-	A repair nail was driven through a coak in the garboard plank SS 1; this nail is not a frame fastener
FL 9	Nail in pilot hole	0.6 x 0.6	Y (1.2 cm diamete r, 0.4 cm deep)	2.0 cm	22.7	69.4	
FL 10	-	-	-	-	21.6	-	
KEEL 2:							
FL 11	Nail in pilot hole	(heavily concreted)	Y (1.5 cm diamete r)	(concret ed)	22.6	44.2	Concreted drilled hole, probably from a nail. FL 11 broke during the shipwreck at a drilled hole at the keel; no sign of a nail on FL 11 is preserved
FL 12	Nail	0.7 x 0.6	-	2.6	22.9	22.9	
FL 13	-	-	-	-	20.8	-	
FL 14	Nail	0.6 x 0.6	-	3.1	22.8	43.6	
FL 15	-	-	-	-	24.2	-	
FL 16	-	-	-	-	22.1	-	
FL 17	Nail	0.5 x 0.5	-	3.2	24.7	71.0	
FL 18	-	-	-	-	22.1	-	
FL 19	-	-	-	-	24.5	-	
FL 20	Nail	0.5 x 0.5	-	--	22.6	69.2	Heavily concreted
FL 21	-	-	-	-	24.2	-	
FL 22	-	-	-	-	21.1	-	
FL 23	Nail	0.6 x 0.5	-	-	22.9	68.2	
FL 24	Nail	0.6 x 0.6	-	-	24.3	24.3	
FL 25	-	-	-	-	23.5	-	
FL 26	Nail	0.5 x 0.5	-		22.8	46.3	
FL 27	-	-	-	-	23.8	-	
FL 28	-	-	-	-	20.9	-	

Table 3.5. Continued

Floor Loc.:	Fast-ener Type:	Fastener's Cross-Sectional Dimensions (cm):	Pilot Hole? (Y/N; diam/depth) (cm):	Min. Fastener Hole Depth (cm):	Distance to Previous Frame (Center to Center) (cm):	Distance to Previous Keel Nail (Center to Center) (cm):	Notes:
FL 29	Nail in pilot hole	0.6 x 0.5	1.2	-	24.1	68.8	
Between FL 29-30	Nail in pilot hole	1.3	-	0.6	11.5	-	Abandoned drilled hole?
FL 30	-	-	-	-	23.8 (to FL 29); 12.9 (to dimple)	23.8	
FL 31	-	-	-	-	24.1	-	
FL 32	Nail	0.6 x 0.5			21.8	45.9	
FL 33	-	-	-	-	24.8	-	
FL 34	-	-	-	-	25.4	-	
FL 35	Nail	0.6 x 0.6	-	4.4	25.6	75.8	
FL 36	-	-	-	-	25.3	-	
KEEL 3:							
FL 37	-	-	-	-	24.6	-	
FL 38	Nail	0.6 x 0.4	-	1.35	23.5	73.4	
FL 39	-	-	-	-	25.0	-	
FL 40	-	-	-	-	23.8	-	
FL 41	Nail	0.6 x 0.6	-	1.6	23.9	72.7	
FL 42	-	-	-	-	22.0	-	
FL 43	Nail	0.6 x 0.6	-	2.2	20.1	42.1	
FL 44	Nail (keel only)	0.5 x 0.5	-	2.8	24.0	24.0	
FL 45	Nail	0.6 x 0.5	-	3.4	24.5	24.5/48.5	
FL 46	Nail	0.7 x 0.6	-	1.9	22.9	22.9	
FL 47	Nail	0.55 x 0.5	Y (1.1 cm; 0.6 cm)	3.8	22.2	22.2	Nail depth is based on concretion protruding from the frame's outer face: FL 47 (formerly UM 16) was torn out of its original position during the shipwreck
FL 48	-	-	-	-	16.0	-	

Table 3.5, Continued

Floor Loc.:	Fast-ener Type:	Fastener's Cross-Sectional Dimensions (cm):	Pilot Hole? (Y/N; diam/ depth) (cm):	Min. Fastener Hole Depth (cm):	Distance to Previous Frame (Center to Center) (cm):	Distance to Previous Keel Nail (Center to Center) (cm):	Notes:
FL 49 (planks only)	Nail in pilot hole	0.6 x 0.5	Y (1.2 cm; 0.4 cm)	2.1	24.1	40.1	
FL 50 (planks only)	-	-	-	--	19.0	-	
FL 51 (planks only)	Nail	0.7 x 0.7	Y (1.1 cm; 0.5 cm)	4.4	14.4	33.4	
"FL 52" (Possible frame location —aft of 2 fasteners)	Nail	1.3 x 1.2	Y; 1.7 cm)	7.5-8.0 (surviving depth)	22.1	22.1	
"FL 52" (Possible frame location — forward of 2 fasteners)	Nail	0.7 x 0.7 (est.)	Y (1.3 cm)	7.5-8.0 (surviving depth)	2.5	2.5	Caulking deposits found in outboard half of hole and in concretion on outer face
Average Spacing	-	-	-	-	**22.9 cm**	**49.0 cm**	-

4) Timber Catalog: Hull Planking

All or part of 18 starboard strakes (PS1-14, PS5A, 10A, 10B, and 12A) and seven port strakes (SS 1-7) were preserved in the hull, totaling 64 hull planks and one wale timber, PS 13. Strakes consisted of one to four planks in the original design of the hull; over time, at least 12 repair planks were added to the hull in damaged areas, so that several strakes now consist of four to five planks (**Figure 3.60-3**).

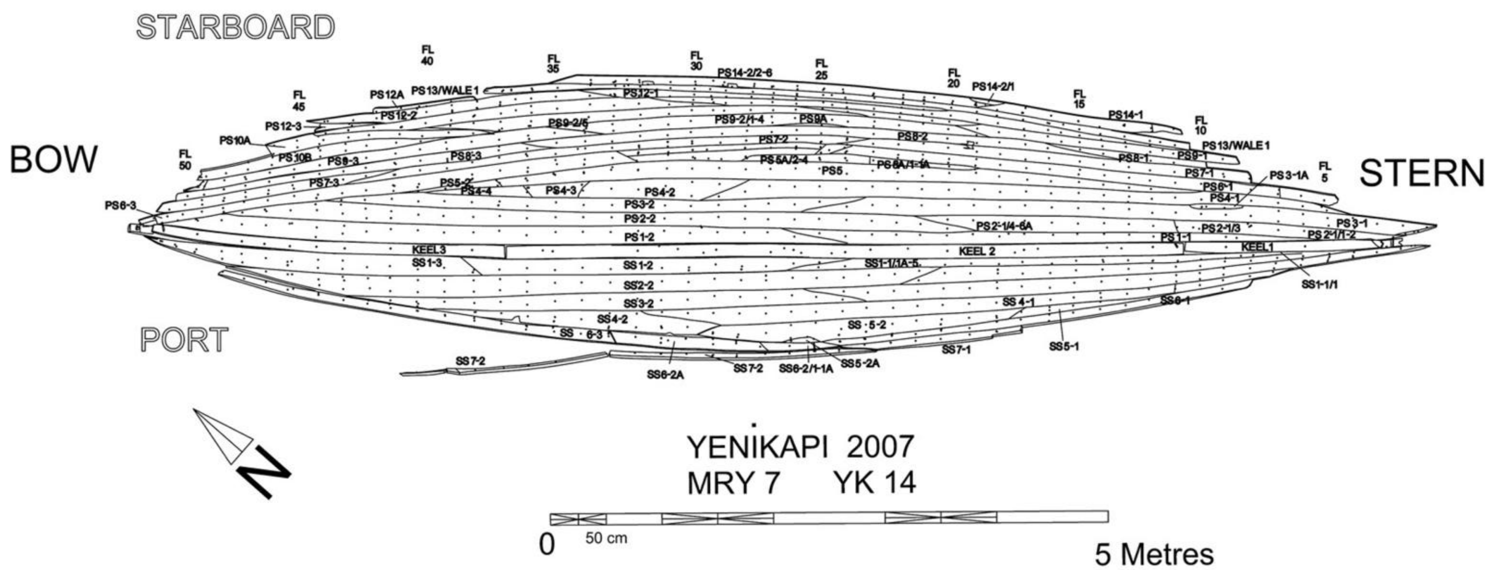

Figure 3.60: Plan of YK 14's hull planking.

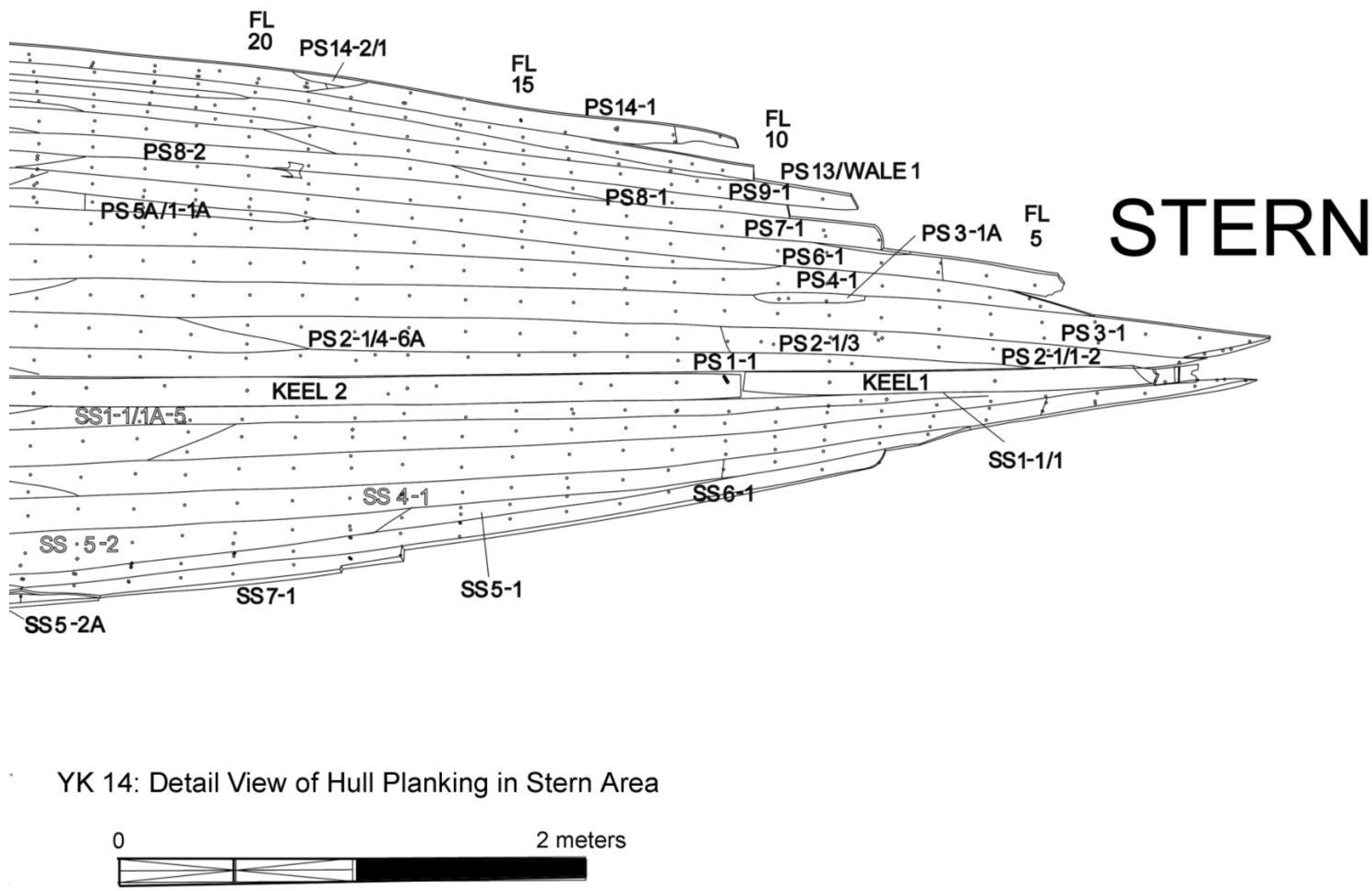

Figure 3.61: The hull planking in the stern area of the ship.

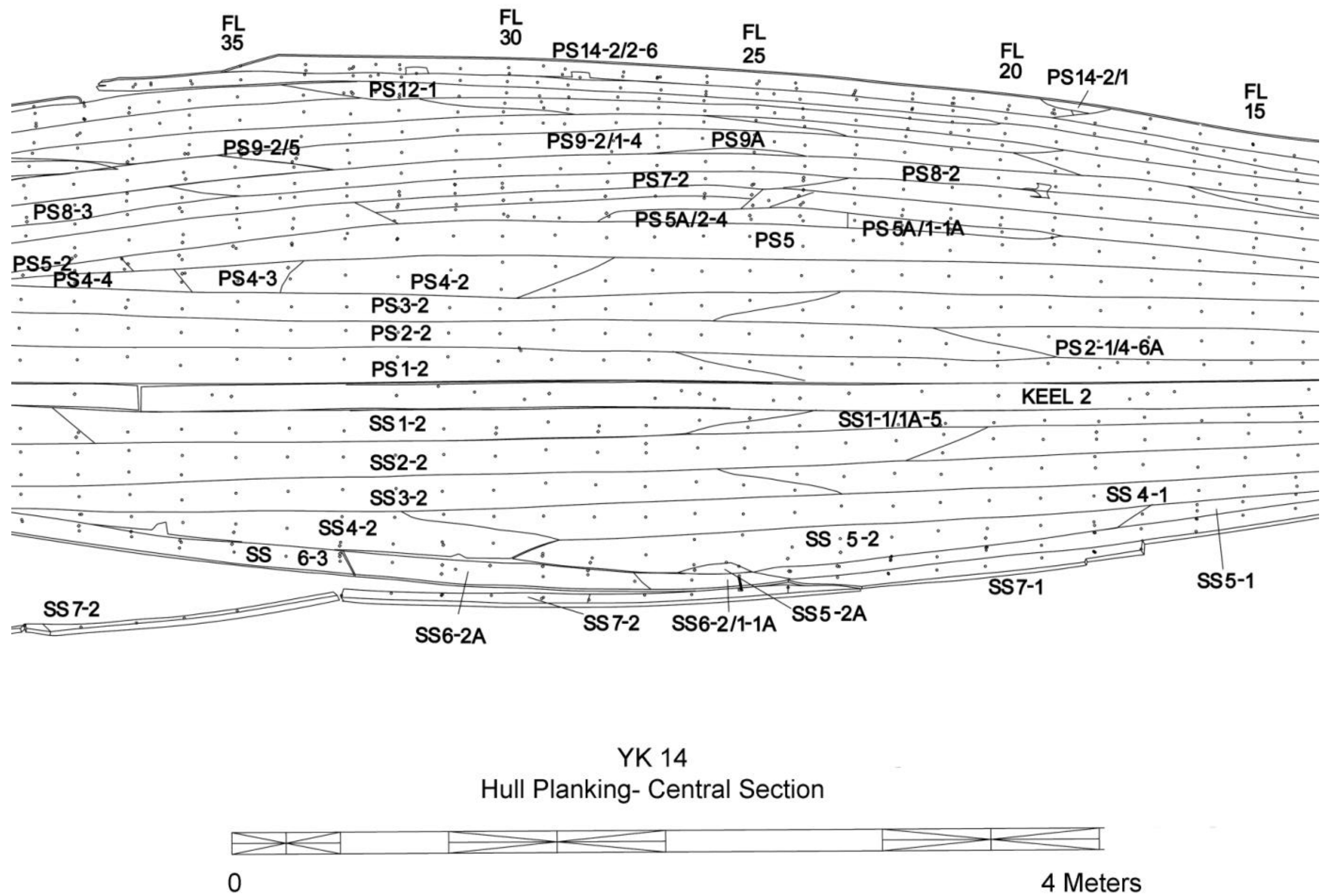

Figure 3.62: The hull planking in the central section of the ship.

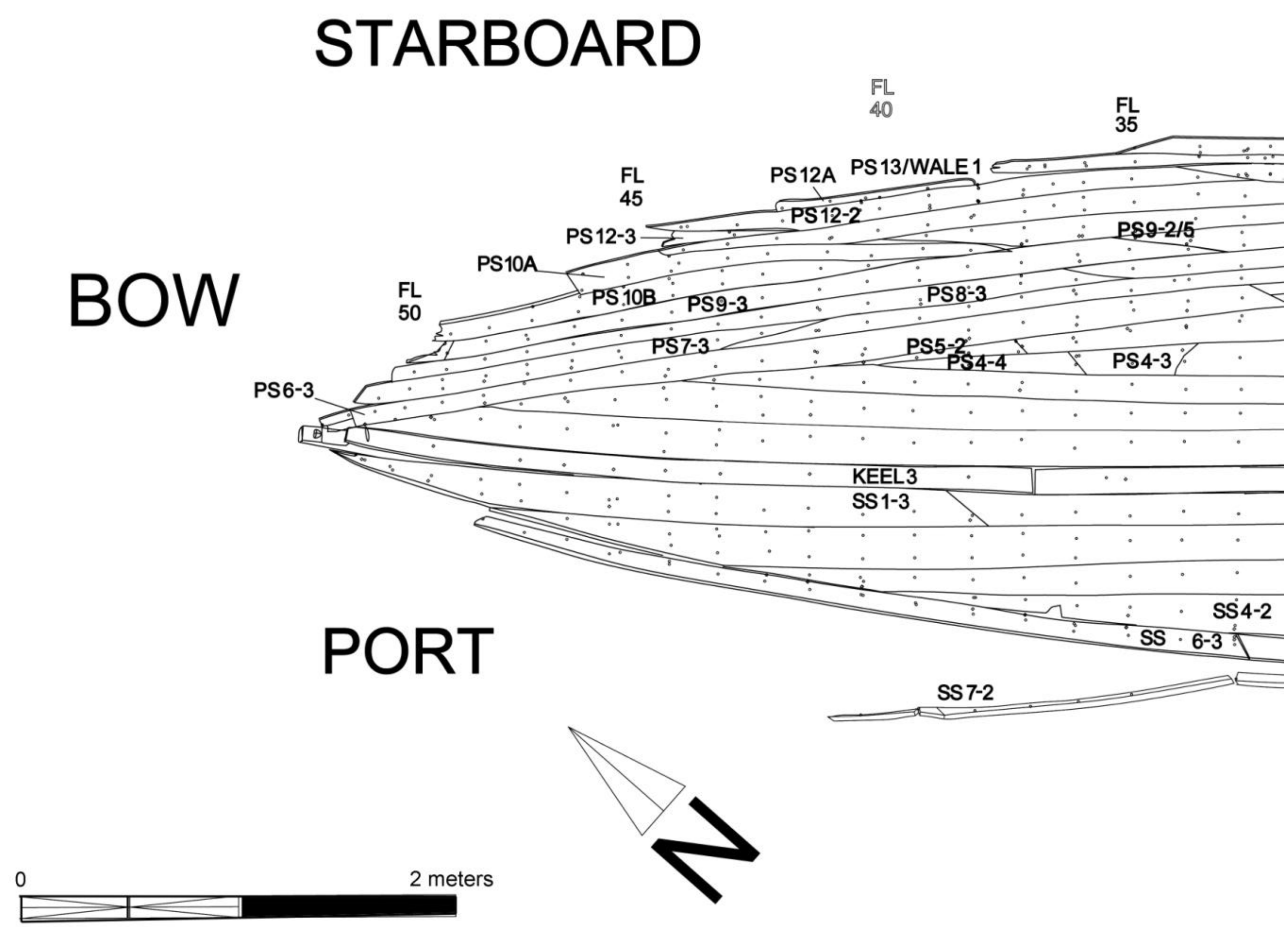

Figure 3.63: The hull planking in the bow section of the ship.

Most of the planks were in good to excellent condition. Most of the original surfaces of the planks were well-preserved, but the mechanical strength of each timber varied greatly, depending on a number of factors including the plank's dimensions, the number of coaks used to edge-fasten the plank (generally, narrower planks tended to be significantly weakened by coaks), and the extent of dry rot damage to the timbers. The poorest preservation occurred in some of the uppermost areas of the shipwreck and in the general area of the bilge, while most of the best preserved planking was located in the bottom of the hull below the turn of the bilge.

Nearly all of the hull planks, as well as the wale, were made from Turkey oak (*Quercus cerris*). One plank, PS 12A, was cut from a timber of Sessile oak (*Quercus petraea*), while two small repair pieces, PS 11-2/6 and PS 14-2/1, were made from European ash (*Fraxinus excelsior*). The hull planks were cut from young timbers. Very few planks had over 30 rings visible at cross sections of plank ends or breaks; most had 10-20 growth rings, and a significant number displayed fewer than ten rings.

Original, fully-preserved hull planks ranged in length from 0.77 m to 6.74 m (see Table 3.6).[319] The widest hull plank was SS 2-2, which had a maximum width of 21.2 cm; a number of other hull planks had maximum widths in the range of 17-20 cm, located primarily in the lower part of the hull before the turn of the bilge. Shorter and narrower

[319] This measurement range does not include PS 14-2/1, a 32.8 cm-long repair scarf made during construction. One plank, PS 5, was likely the longest plank in the hull before it was repaired; the entire strake, which includes PS 5 and PS 5-2, a repair plank, is over seven meters long.

planks tended to be used at the turn of the bilge or towards the ends of the hull (in particular, in strakes PS 6-8 and SS 6-7), where several served as stealers or drop strakes (e.g., PS 10A, 10B, and 12A), while the largest, widest planks were used in the relatively flat bottom of the hull before the turn of the bilge (including strakes PS 1-4 and SS 1-4). As with most shell-built ships, there is a clear attempt to shape symmetrical runs of planking in the first few strakes used in the hull. These are very similar in length and shape, although four shorter pieces were used in strake SS 1 and only two were used in PS 1, perhaps due to a lack of larger planks during construction.[320] After strake 3, the hull planking became more irregular, as shorter pieces were used in strakes SS 4 and 5, while longer, more regular pieces appear to have been used in strakes PS 4 and PS 5. Some planks terminating in the area of the turn of the bilge may have been trimmed down. This would likely explain the thin, tapered forward ends of SS 3-2, PS 4-4, and the forward end of PS 5, which were fastened to the previous strake with unusually short coaks (**Figure 3.64**).

Figure 3.64: PS 4-4, a tapered plank whose forward end (left) was likely trimmed to a point after being edge-fastened to the hull.

[320] The butt scarf ends between SS 1-1/1 and SS 1-1/1A-5 were roughly shaped with an adze, which may have been due to a break in the plank in this area. Based on the two coaks in the upper edge of SS 1-1/1, this scarf probably resulted from a modification made during construction; perhaps SS 1-1/1 was accidentally separated from SS 1-1/1A-5, and later both pieces were cut down and re-installed.

The thicknesses of hull planks other than the garboard strakes ranged from 0.8 cm to 4.4 cm, with an average thickness of 2.3 cm (**Table 3.6**). In a few areas the hull planking appears to be slightly compressed, but in most areas the planks have preserved their original thicknesses.[321] The garboard strakes ranged in thickness between 1.1 to 4.4 cm on their inboard edges and 1.7 to 3.2 cm on their outboard edges, with an average thickness of 2.8 cm on their inboard edges. The hull's sharp turn of the bilge was planked using relatively narrow strakes, generally under 15 cm in width. Hull planks were edge-fastened with coaks on all plank sseams from the keel up to the strake below the first wale, PS 13, located at the ship's waterline. The wale was not edge-fastened to neighboring strakes, with the exception of coaks used at the scarf ends of adjacent strakes. The scarf joint between PS 14-1, PS 14-2/1 and PS 14-2/2-6 was also fastened with coaks, but the planks were only fastened to each other and not to the wale.

The six garboard planks from the ship were recovered complete; they consist of two planks on the starboard side (PS 1-1 and PS 1-2) and four planks on the port side (SS 1-1/1, SS 1-1/1A-5, SS 1-2, and SS 1-3). The garboards' keel edges are beveled to fit snugly into the keel rabbet, with sharper bevels and hood ends occurring towards the ends of the hull, up to 1.7 cm wide on the starboard (Keel/PS 1) side and 3.8 cm wide on the port (Keel/SS1) side. Hood ends of strakes above the garboards were cut wider, up to 4.8 cm wide on SS 3-1 and PS 3-1 (**Figure 3.65**).

[321] Evidence of compression of the planking on other shipwrecks at Yenikapı included ovoid cross sections of coaks visible on plank edges, and raised areas at frame locations, where the presence of a frame protected the planking from compression. The thickness of planks on YK 14 is consistent with those of other Byzantine vessels from Yenikapı documented by INA.

Figure 3.65: The aft-hood end of PS 3-1 in situ.

At the keel/garboard plank seams, a combination of angled wooden coaks and iron nails were used to fasten the garboards into the keel rabbet; the coaks were driven upwards until they protruded from the inner face of the keel, where they were cut. On their outboard edges, the garboards were fastened to the adjacent strakes with regularly spaced coaks, in the style of all of the edge-fastened planking up to the first wale, PS 13. Hood ends of the hull planks were fastened to the keel and end-posts with iron nails, most of which were driven through drilled holes, although a few wooden coaks were also used for this purpose.

Table 3.6: Hull Planking Dimensions

Plank:	Complete/ Condition of Ends:	Length (m):	Width Range (cm):	Thickness Range (Upper/ Keel Edges) (cm):	Average Thickness (cm):	Scarf End Types:	Notes:
STAR-BOARD PLANKS							
SS 7-1	Original forward end is original; broken aft end	1.66	9.2-11.6	2.0-2.3/ 2.0-2.5	2.2	'S' scarf (forward end); aft end is broken	
SS 7-2	Both ends are original	4.40	6.7-8.2	2.0-2.8/ 2.0-2.7	2.4	Diagonal scarf ends	
SS 6-1	Original forward end; broken aft end	3.91	7.5-12.0	1.8-2.7/ 1.8-2.5	2.2	'S' scarf (forward end)	
SS 6-2/ 1-1A	Both ends are original	0.69	7.2-9.3	1.7-2.5/ 2.4-2.5	2.3	Roughly-cut diagonal scarf (forward end—repair scarf); 'S' scarf (aft end)	Aft end roughly cut down for repair plank SS 6-2A
SS 6-2A	Both ends are original	1.43	9.0-14.5	2.0-2.4/ 2.1-2.5	2.1	Short diagonal scarf ends	Repair plank
SS 6-3	Broken forward; original aft end	3.61	9.3-14.0	1.6-2.7/ 2.1-2.6	2.3	Diagonal Scarf (aft end—repair scarf)	
SS 5-1	Both ends are original	1.59	9.4 (max. w.)	1.8-2.7/ 2.0-2.6	2.2	Point (aft end); diagonal scarf (forward end)	
SS 5-2	Both ends are original	2.95	9.9-19.9	1.8-2.7/ 2.2-2.8	2.3	Diagonal scarf (both ends)	

Table 3.6. Continued

Plank:	Complete/ Condition of Ends:	Length (m):	Width Range (cm):	Thickness Range (Upper/ Keel Edges) (cm):	Average Thickness (cm):	Scarf End Types:	Notes:
SS 5-2A	Both ends are original	0.29	4.6-5.1	2.4-2.6/ 2.6-3.1	2.6	Short diagonal scarf ends	Repair plank
SS 4-1	Both ends are original	5.92	9.8-16.4	2.2-2.9/ 2.0-2.8	2.4	Diagonal scarf (aft end); ‘S’ scarf (forward end)	
SS 4-2	Both ends are original	2.64	4.0-20.0	1.1-2.6/ 2.0-2.8	2.2	Point (forward end); diagonal and ‘S’ scarf (upper/keel edges—aft end)	
SS 3-1	Both ends are original	5.67	14.4-20.0	1.8-2.6/ 1.8-2.5	2.2	‘S’ scarf (forward end); hood end (aft end)	
SS 3-2	Both ends are original	5.70	11.4-16.2	1.9-2.4/ 2.0-2.7	2.3	Diagonal scarf (forward end); ‘S’ scarf (aft end	
SS 2-1	Both ends are original	4.54	5.1-15.3	2.1-2.4/ 2.1-2.5	2.3	Diagonal scarf (forward end); hood end (aft end)	
SS 2-2	Both ends are original	6.467	16.0-21.2	2.0-2.6/ 2.1-2.8	2.4	Diagonal scarf (both ends)	
SS 1-1/1	Both ends are original	0.77	1.0-7.3	2.4-3.0/ 1.1-2.9	2.7	Butt scarf (forward end); hood end (aft end)	

Table 3.6, Continued

Plank:	Complete/ Condition of Ends:	Length (m):	Width Range (cm):	Thickness Range (Upper/ Keel Edges) (cm):	Average Thickness (cm):	Scarf End Types:	Notes:
SS 1-1/1A-5	Both ends are original	4.31	1 9.1-3.3	1.9-3.1/ 2.3-3.6	2.8	'S' scarf (forward end); butt scarf (aft end)	
SS 1-2	Both ends are original	3.51	14.2-16.5	1.8-3.0/ 2.2-3.6	2.8	Diagonal scarf (forward end); 'S' scarf (aft end)	SS 1-2/ SS 1-3 scarf not fastened with coaks, cut with wide bevel (2.1-2.6 cm wide on SS 1-2; 2.2-2.3 cm on SS 1-3). One of two scarf ends of this type (see also PS 10A)
SS 1-3	Both ends are original	3.07	18.3-19.8	2.55-3.2/ 2.9-4.4	3.1	Diagonal scarf (both ends)	
PORT PLANKING							
PS 1-1	Both ends are original	4.95	4.5-13.5	1.1-2.9/ 2.6-3.2	2.4	'S' scarf (forward end); hood end (aft end)	
PS 1-2	Both ends are original	6.43	15.1-19.9	2.6-2.9/ 2.9-3.5	3.1	Diagonal scarf (forward end); 'S' scarf (aft end)	
PS 2-1/1-2	Both ends are original	1.43	9.4-11.9	1.1-2.6/ 1.1-2.8	2.3	Diagonal scarf (forward end—cut for a repair); hood end (aft end)	Repair plank
PS 2-1/3	Both ends are original	0.74	9.7-11.6	2.1-2.4/ 2.1-2.4	2.3	Diagonal Scarf ends	Repair plank

Table 3.6, Continued

Plank:	Complete/ Condition of Ends:	Length (m):	Width Range (cm):	Thickness Range (Upper/ Keel Edges) (cm):	Average Thickness (cm):	Scarf End Types:	Notes:
PS 2-1/ 4-6A	Both ends are o riginal	2.38	11.8-14.3	2.1-2.4/ 2.3-2.5	2.2	'S' scarf (forward end); diagonal scarf (aft end—cut for a repair)	
PS 2-2	Both ends are original	6.74	12.2-17.0	1.7-2.8/ 2.1-3.1	2.3	Diagonal scarf (forward end); 'S' scarf (aft end	
PS 3-1	Both ends are original	5.74	11.7-19.3	1.8-2.8/ 2.0-3.6	2.2	'S' scarf (forward end); hood end (aft end)	
PS 3-1A	Both ends are original	0.47	5.0 (max. w.)	1.8-2.7	2.6	Rounded ends	Repair plank/graving piece. Installed at PS 3/4 plank seam, probably to replace rotten area
PS 3-2	Both ends are original	4.84	10.8-12.8	1.3-2.5/ 1.9-2.7	2.2	Diagonal scarf (forward end); 'S' scarf (aft end)	
PS 4-1	Both ends original	5.90	12.1-17.4	1.8-2.2/ 2.1-2.3	2.0	Diagonal scarf (forward end); diagonal scarf (aft end)	

Table 3.6, Continued

Plank:	Complete/ Condition of Ends:	Length (m):	Width Range (cm):	Thickness Range (Upper/ Keel Edges) (cm):	Average Thickness (cm):	Scarf End Types:	Notes:
PS 4-2	Both ends are original	1.55	14.8-19.7	2.0-2.5/ 2.2-2.7	2.3	Diagonal scarf (forward end—cut for a repair); diagonal scarf (aft end)	
PS 4-3	Both ends are original	0.57	10.8-12.4	1.7-2.4/ 1.7-2.0	2.1	Diagonal scarf ends	Repair plank
PS 4-4	Both ends are original	0.99	11.1 (max. w.)	1.4-2.1/ 1.3-2.2	1.8	Point (forward end); diagonal scarf (aft end—cut for a repair)	Slightly compressed plank?
PS 5	Both ends are original	6.112	8.0-16.2	2.0-2.5/ 1.8-2.8	2.2	Diagonal scarf (forward end—cut for a repair); point (aft end)	
PS 5-2	Both ends are original	1.08	7.3 (max. w.)	1.4-2.1/ 1.4-1.9	1.7	Point (forward end); diagonal scarf (aft end)	Repair plank. Slightly compressed?
PS 5A/ 1-1A	Both ends are original	1.01	3.4-6.2	1.6-2.1/ 0.8-1.9	1.9	Butt scarf (forward end); rounded point (aft end)	Repair plank

Table 3.6, Continued

Plank:	Complete/ Condition of Ends:	Length (m):	Width Range (cm):	Thickness Range (Upper/ Keel Edges) (cm):	Average Thickness (cm):	Scarf End Types:	Notes:
PS 5A/2-4	Both ends are original	1.22	4.2-7.6	1.5-2.0/ 2.0-2.5	1.9	Diagonal scarf/rounded point (forward end); butt scarf (aft end--repaired)	Slightly compressed plank?
PS 6-1	Original forward. end; broken aft end	4.59	8.1-13.7	1.7-2.3/ 1.4-2.3	1.9	Diagonal/ 'S' scarf (forward end)	
PS 6-2/1	Both ends are original	0.323	8.4 (max. w.)	1.7-1.9/ 1.5-1.6	1.4	Irregular/ 'S' scarf (forward end); Diagonal/ 'S' scarf (aft end)	Repair plank
PS 6-2/2-4	Both ends are original	1.86	9.8-15.0	1.4-2.1/ 1.4-2.3	1.9	'S' scarf (forward end); irregular/ 'S' scarf (aft end)	Repair plank
PS 6-3	Broken forward end; original aft end	4.68	8.5-14.5	0.8-2.6/ 1.4-2.5	2.2	Diagonal scarf (aft end)	
PS 7-1	Original forward end; broken aft end	3.75	10.3-13.5	1.8-2.4/ 2.0-2.4	2.0	'S' scarf (forward end)	
PS 7-2	Both ends are original	4.84	8.3-8.7	1.2-2.2/ 1.7-2.4	1.9	'S' scarf (both ends)	
PS 7-3	Broken forward end; original aft end	2.26	10.3-11.0	1.5-2.2/ 1.5-2.5	2.1	'S' scarf (aft end)	

Table 3.6, Continued

Plank:	Complete/ Condition of Ends:	Length (m):	Width Range (cm):	Thickness Range (Upper/ Keel Edges) (cm):	Average Thickness (cm):	Scarf End Types:	Notes:
PS 8-1	Original forward end; broken aft end	1.42	8.2-9.5	2.2-2.7/ 2.2-2.3	2.3	'S' scarf (forward end)	
PS 8-2	Both ends are original	5.74	10.1-11.0	1.75-2.55/ 1.95-2.45	2.2	'S' scarf (both ends)	
PS 8-3	Broken forward end; original aft end	3.50	8.1-12.5	1.8-2.4/ 1.4-2.3	2.0	'S' scarf (aft end)	
PS 9-1	Original forward end; broken aft end	2.56	8.6-14.2	1.1-1.7/ 1.9-2.7	2.5	'S' scarf (forward end, upper edge); diagonal scarf (forward end, keel edge)	
PS 9-2/1-4	Both ends are original	3.68	11.4-16.2	2.2-2.4/ 2.0-2.7	2.6	Diagonal scarf (forward end—cut for a repair); diagonal scarf (aft end)	
PS 9-2/5	Both ends are original	0.31	1.8-8.1	1.7-2.0/ 2.0-2.3	2.0	Diagonal scarf/point (forward end); Diagonal scarf (aft end)	Repair plank
PS 9-3	Broken forward end; original aft end	3.65	10.5-14.7	2.0-2.5/ 1.9-2.3	2.2	Diagonal scarf (aft end)	
PS 9A	Both ends are original	0.62	0.15-3.4	1.6-2.2	2.0	Points (both ends)	Repair made during construction

Table 3.6. Continued

Plank:	Complete/ Condition of Ends:	Length (m):	Width Range (cm):	Thickness Range (Upper/ Keel Edges) (cm):	Average Thickness (cm):	Scarf End Types:	Notes:
PS 10-1	Both ends are original	1.68	6.5-8.1	2.1-2/ [could not measure keel edge]	2.4	'S' scarf (forward end); diagonal scarf (aft end)	
PS 10-2	Both ends are original	4.06	9.9-15.2	1.9-2.3/ 2.1-2.2	2.4	'S' scarf (both ends)	
PS 10A	Both ends are original	2.11	7.0-17.0	1.9-2.7/ 1.8-2.3	2.1	Short diagonal scarf (forward end); diagonal scarf (aft end)	Short, beveled diagonal scarf at forward end, similar to the SS 1-2/ SS 1-3 scarf (bevel width = 0.5-0.8 cm). The forward scarf was not fastened with coaks
PS 10B	Both ends are broken	2.27	6.3-19.1	2.0-2.6 cm/ 1.9-2.6 cm	2.3	Point (aft end—damaged)	
PS 11-1	Both ends are original	4.84	2.4-10.2	1.5-2.7/ 1.5-2.8	2.1	'S' scarf (forward end); rounded point (aft end)	
PS 11-2/ 1-5	Both ends are original	3.39	4.7-15.8	2.2-2.5/ 2.3-2.6	2.4	Truncated 'S' scarf (forward end—repaired); 'S' scarf (aft end)	
PS 11-2/6	Both ends are original	0.33	6.0 (max. w.)	2.2-2.2/ 2.3-2.6	2.3	Rounded point (forward end); butt scarf (aft end).	Repair plank

Table 3.6, Continued

Plank:	Complete/ Condition of Ends:	Length (m):	Width Range (cm):	Thickness Range (Upper/ Keel Edges) (cm):	Average Thickness (cm):	Scarf End Types:	Notes:
PS 12-1	Both ends are original	3.30	3.3-11.1	1.5-2.8/ 2.2-2.7	2.4	Diagonal scarf (forward end); point (aft end)	
PS 12-2	Both ends are original	2.85	12.1-15.6	2.0-2.7/ 2.5-2.7	2.6	'S' scarf (both ends)	
PS 12-3	Broken forward end; original aft end	0.57	9.0 (max. preserved width)	2.4-2.6/ 2.3-2.4	2.4	'S' scarf (aft end)	
PS 12A	Both ends are broken	0.96	1.5-5.75	2.4-2.6/ 2.5-2.6	2.5	-	
PS 13 (WALE)	Both ends are broken	6.91	8.0-10.45	3.6-7.2 (max. thickness range)	-	-	
PS 14-1	Forward end original; aft end broken	1.90	10.8-11.6	1.8-2.5/ 2.1-2.6	2.4	'S' scarf (forward end)	
PS 14-2/1	Both ends are original	0.33	3.8 (max. width)	1.7-2.3 (both edges)	1.9	Pointed ends	Repair to PS 14-1/14-2 scarf ends made during construction
PS 14-2/ 2-6	Both ends are original	3.94 (3.99 with pitch repair on forward end)	11.2-12.0	1.7-2.6/ 2.1-2.8	2.4	Diagonal scarf (forward end); 'S' scarf (aft end, with repair)	

In most cases, the planks comprising each strake were fastened end-to-end in diagonal or diagonal/S-scarfs. These varied in length on original planks from 16.8 cm to 103 cm, with average lengths of approximately 50 cm (**Figures 3.66a-b**).[322] With a few exceptions, the scarf ends of planks were fastened to each other and to the neighboring strakes with coaks. Typically two to three coaks were used per scarf, depending on its length; no planking scarf ends in the hull were toenailed.[323] Coaks at the tips of plank scarfs or tapered planks were cut flush on the scarf seam and later caulked over (**Figure 3.67**). In a few areas, shorter, diagonal scarf ends with lengths of 7.0-12.5 cm and having beveled edges were also used; these were not fastened with coaks. There was a greater degree of variability in the shapes of scarf ends for repair pieces. Repair pieces such as PS 6-2/1 and PS 9-2/5 were replacements for damaged diagonal or 'S' scarfs, and retained the shape of the original, removed sections of planking. Repair planks usually had much shorter and more roughly-shaped diagonal scarfs (usually under 10 cm in length) or butt scarfs and were not fastened with coaks, having been added after the initial construction of the hull (**Figure 3.68**).[324] The edges of several repair planks are beveled from the outer to the inner faces, reflecting the angle required to cut out the damaged section of the original plank.

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[322] For planking scarf types and terminology, see Steffy 1994, 292, Fig. G-11b. Most of the scarfs on YK 14 resemble Steffy's curved or S-scarf, or are a combination of S- and diagonal scarf with only one curved section.

[323] However, see UM 5 in the UM Timbers section. Toenailed scarf ends occur on several other Byzantine ships, including YK 11, YK 23, and a few scarf ends on the Serçe Limanı ship, and are also a feature of earlier Roman ship construction (Ucelli 1950, 153, Fig. 153; see also Bass et al. 2004, 107-8).

[324] A few scarfs on repair planks were more precisely cut, such as the ends of the graving piece SS 5-2A.

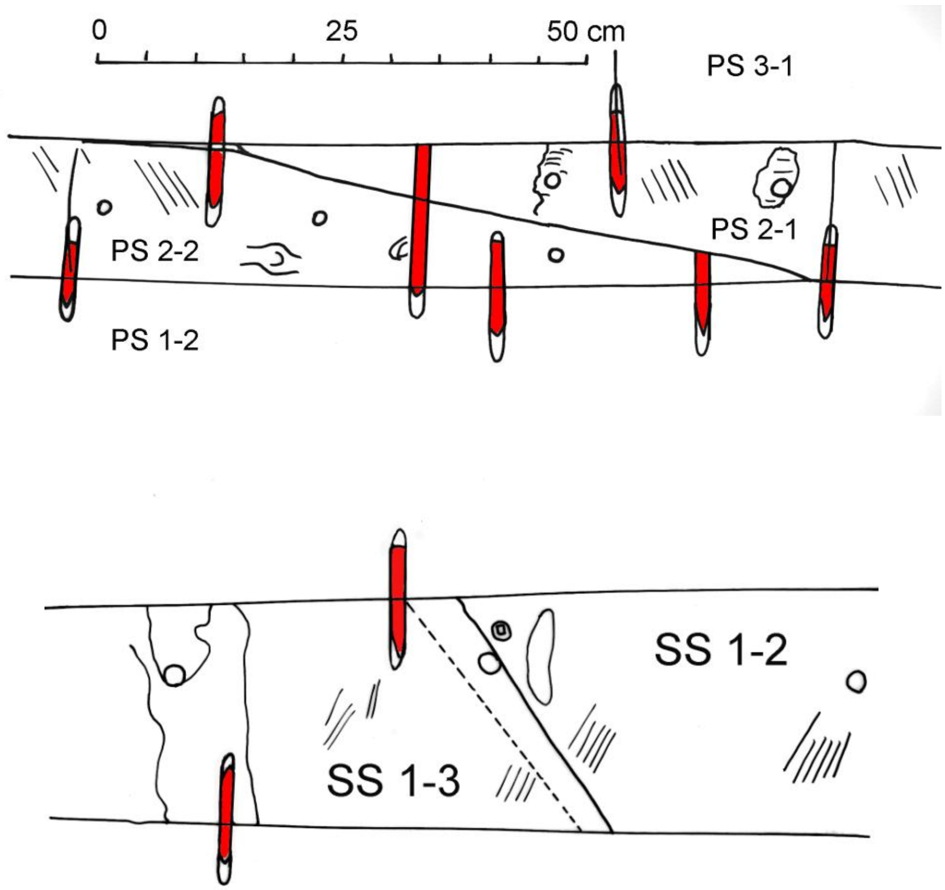

Figure 3.66a-b: Plank scarf types used on YK 14. The upper drawing, of the PS 2-1/2-2 scarf (a), is of an S-scarf fastened with three coaks, in addition to coaks located near the scarf end. This is a fairly typical scarf type in the lower hull of the ship. The lower scarf (b) is a more unusual short diagonal scarf between SS 1-2 and SS 1-3 with a beveled edge which was not fastened with coaks.

Figure 3.67: Detail of a coak on the after-diagonal scarf of PS 10-2, which had been cut and caulked over.

Figure 3.68: The plank scarf between SS 6-2A, a repair plank (at left), and SS 6-3, an original plank, before dismantling. Note the thick caulking in the scarf seam.

Elongated scarfs, such as those seen on YK 14, are generally considered to be more characteristic of shell-based construction, since simple butt scarf ends would have sufficed if planking was fastened to pre-erected frames.[325] In YK 14's hull, planking was not edge-fastened above PS 12, the strake below the first wale, PS 13. However, the diagonal scarfs on PS 14, the strake above the first wale, were fastened with coaks. The aft scarf end of PS 14-2/2-6 was fastened to PS 13 with a single coak near its tip, and with a second coak fastening it to the now-lost PS 14-3 plank (**Figure 3.69**). UM 12, a planking fragment that may be from the upper section of the hull, shows evidence for an 'S' scarf and a 'Z' or three-plane scarf on its edges, but no edge fasteners were used. Coak-fastened- and elongated scarfs seem to be favored in the upper section of the hull even where they were not strictly necessary.

[325] Bass et al. 2004, 107-9, 162; see also Kahanov et al. 2004, 124-25. Steffy commented on the use of three-plane scarfs in the Serçe Limanı ship's hull: "Why three-planed scarfs were used, rather than plain butt joints, is a mystery to me. The existence of at least two butt joints indicates that the builders were not strangers to them. Three-planed scarfs were a product of mortise-and-tenon joinery, where there were no standing frames for support and such long edges were necessary to assure a strong seam. In this hull, however, they merely seemed to expose additional seam lengths to seepage, while appearing to provide less solid attachment than would have been the case if the planks had been butt-joined. This seems especially curious when one realizes that the scarfs were mostly in the center of the hull, where there was little strain on the planks" (Bass et al. 2004, 162). In Dutch shell-first construction, in which temporary cleats were employed to assemble the hull planking rather than planking edge fasteners, various three-planed, diagonal, or stop-splayed scarfs were also used (Lemée 2006, 113, 137, 204, 243, 299).

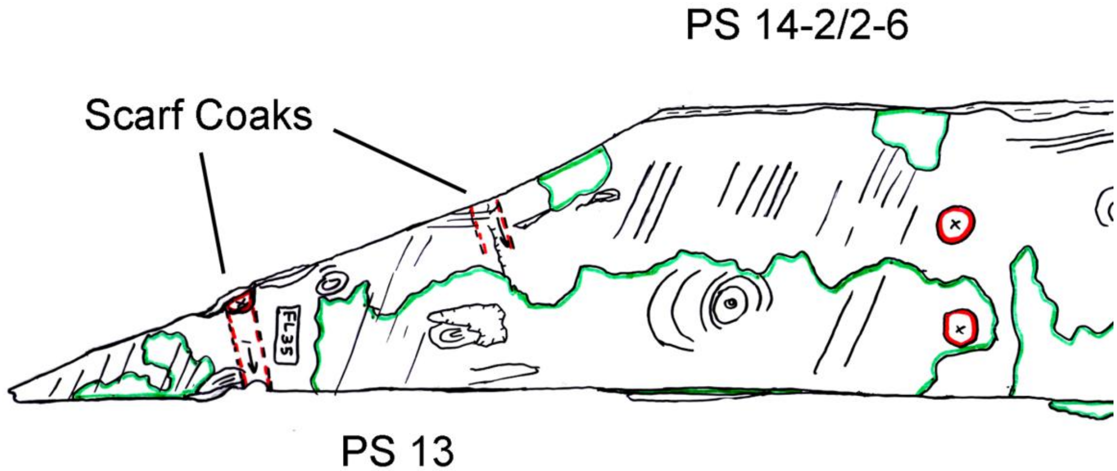

Figure 3.69: Forward scarf of PS 14-2/2-6; note the two coak locations. The lower coak was driven into the wale, PS 13, located below it.

The scarf between planks PS 14-1, PS 14-2/1, and PS 14-2/2-6 is a unique type (**Figures 3.70-2**). Although the forward end of PS 14-1 and the aft end of PS 14-2/2-6 resemble a typical diagonal or 'S' scarf end, a crescent-shaped piece, PS 14-2/1, was inserted in the scarf's outboard edge; all three pieces were fastened with coaks that were used only to fasten the planks to each other and not to the wale timber below. A small triangular gap was situated in the center of the scarf, with an exposed coak protruding at the edge of PS 14-2/2-6, perhaps the reason for the loss of the scarf tip. This gap was filled with a plug made of a mixture of hair and pitch, approximately 5.2 x 2.5 cm on its inner face and 6.9 x 3.0 cm on its outer face. The plug itself is 3.3 cm thick, about 1 cm thicker than the surrounding planking; most of the plug's excess thickness bulged from the plank's outer face. This unusual configuration is probably a repair to the planking that occurred during the construction of the hull; the tip of the diagonal or S-scarf being cut for PS 14-2/2-6 probably broke off when the shipwright drilled coak holes to edge-fasten the two scarf ends or when coaks were driven to fasten the scarf. The scarf ends on both planks were cut down and a third piece, PS 14-2/1, was inserted in the gap and fastened to the other two with coaks. The forward-most coak hole is particularly unusual in that a small wooden plug, 0.9 cm long and 1.1 cm in diameter, was inserted into the lower edge of the coak hole in PS 14-2/2-6 to block the remaining, unfilled section of the hole.

Figure 3.70: The scarf between PS 14-1 (right), 14-2/1 (center, labeled), and PS 14-2/2-6 (left), before dismantling.

Figure 3.71: Detail of the caulking plug of hair and pitch at the PS 14-1/PS 14-2 scarf.

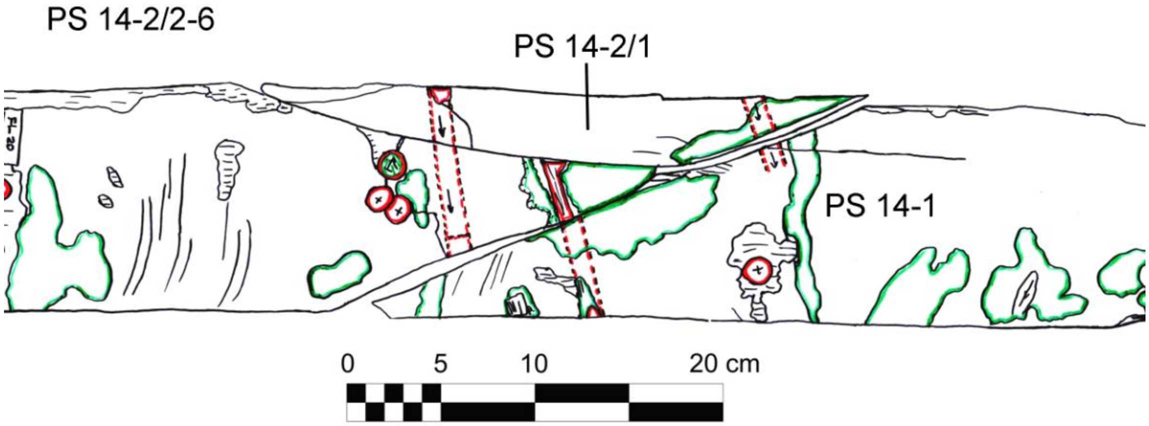

Figure 3.72: Drawing of PS 14-1/PS 14-2 scarf, showing coaks in the scarf (dashed lines outlined in red).

Tool Marks and Other Surface Features of the Hull Planking

Saw marks on most of the hull planks are usually fairly widely spaced (0.3-0.5 cm or more) and tend to run in relatively uniform directions, except at occasional features such as knots, which were more difficult to cut (**Figure 3.73**). Saw marks on some of the garboard planks, particularly SS 1-2 and SS 1-3, were more closely spaced and run in several directions in some areas. Arc-shaped marks are apparent on SS 1-2's aft scarf; these may be 'saw return marks' caused by pulling the saw back in a curved motion, similar to tool marks described on one of the floor timbers from the Serçe Limanı ship.[326]

[326] Bass et al. 2004, 100. Curved marks which are likely saw return marks were also found on the sawn aft face of futtock F 37.

Figure 3.73: Saw marks on the inner face of plank PS 9-3. Note the saw marks' relatively wide spacing and uniform orientation of the marks; these features were typical on hull planks that were not dubbed with adzes.

Many of the sawn surfaces of the planks were further dubbed with adzes in some areas to the desired thickness. Adze marks on many of the planks are concentrated along their inboard and outboard edges, most likely because the hull planks were trimmed to a roughly uniform thickness after being fastened together. In some areas, the shipwright cut shallow depressions into the inner faces of the planking to accommodate floor timbers, an indication that these planks were assembled before the floors were installed at these locations. Another sign of the insertion of floor timbers after the assembly of the hull planking is the presence of score marks at the edges of frame locations, sometimes covered by a layer of pitch (**Figure 3.74-5**). These are most frequently found at the turn of the bilge on either side of the hull, in areas that may have been less susceptible to wear or further dubbing with adzes. Similar score marks may have existed in other areas along proposed frame edges but could have been adzed away later as both the planking and floor timbers were trimmed to fit flush with each other.[327] Many more score marks were found at the locations of coaks.[328]

Some areas of the hull planking were charred to facilitate bending and twisting of specific planks, particularly towards the ends of the hull where it was necessary to fasten them to the end-posts. The charring of timbers to facilitate their bending during construction is an old shipbuilding practice used before the advent of steam-bending in wooden shipbuilding. The process involves soaking the plank in salt water, after which it is suspended over a fire with one end weighted down. The fire's heat causes shrinkage on the face closest to it, which, in turn, bends the plank. This process required a great

[327] This has been proposed as an explanation for the absence of many score marks marking the locations of edge fasteners in some ancient shipwrecks (Steffy 1985a, 90).

[328] Score marks at frame-edge locations and edge fastener positions have been found on many other shell-built or mixed-construction Mediterranean shipwrecks, including the Ma'agan Mikhael ship (marks both for aligning planks and frames; Mor 2003, 167-68), the Kyrenia ship (score marks at edge fasteners; Steffy 1994, 43), the third-century B.C.E. Marsala or Lilybaeum ship (score marks at frame edges and mortise and tenons, and also alphabetical marks; Johnstone 1981, 194-239), the first –century B.C.E. Chrétienne A ship (score marks at frame edges; Dumas 1964, 159); the fourth-century Yassıada ship (a score mark at a frame edge; van Doorninck 1976, 125), the seventh-century Yassıada ship (score marks at frame locations; Bass and van Doorninck 1982, 38, Fig. 3-11, 3-12; 59), and the fifth-century C.E. Dor D wreck (at frame edges; Kahanov and Royal 2001, 260-2). On the Yenikapı shipwrecks, score marks were found on seven of the shipwrecks: on YK 1 and 11 at frame edges, and at locations of some edge fasteners and frame edges on YK 2, 4, 5, 23, and 24.

deal of experience to perform correctly and involves propping the plank over a fire for periods of up to several hours, while keeping the upper side wet (**Figure 3.75**).[329]

Figure 3.74: Score mark at the location of one edge of FL 32, on the inner face of plank SS 7-2.

[329] Burning and/or soaking in saltwater to bend hull planking is a recorded technique in Renaissance-era Iberian shipbuilding (Smith 1993, 78) and in early seventeenth-century Dutch shipbuilding, where it is mentioned both in treatises and attested in charred areas on the hull planking of Dutch shipwrecks (Lemée 2006, 243, 247; Hoving 2012, 61). The technique is still practiced by Indonesian and Pakistani boat builders in recent times (Hawkins 1982, 92; Greenhill 1971, 79). Damianidis (1991, 101) describes a similar process in boat construction in modern Greece; hybrid *Pinus brutia* planking is first seasoned, and, before use, is soaked in salt water for up to a few hours before fastening to the hull. During construction in the winter, the lower part of the plank is heated with a fire, while the upper part is kept wet, while in the summer, the heat of the sun is deemed enough to add to the planks' flexibility (Damianidis 1991, 100-1). Charring can also be used to prevent rot (Smith 1993, 67).

Figure 3.75: Example of charring on the inner faces of hull planks at the bow (PS 1-2, 6-3, 7-3, and 8-3).

Charred areas were noticed on a number of the hull planks on YK 14. Similar evidence has been found on other Byzantine-era ships from Yenikapı and Tantura Lagoon, and possibly on the late fourth-century B.C.E. Kyrenia ship as well.[330] On YK 14, planks in the first few strakes were charred and bent into a twisted shape in order to fasten their hood ends to the endposts (**Figure 3.76**).[331] On some planks, it was possible to differentiate between the initial sawing, which was preserved in burnt areas, and subsequent adze dubbing which removed saw marks on the burnt surface (**Figure 3.77**; **Table 3.7**).[332] The dubbed areas are visible as depressions next to or between charred areas; these areas were sometimes preserved under pitch, indicating that they are original features of the hull planks rather than the result of wear or weathering after the sinking of the ship or damage incurred during excavation.

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[330] Charring was observed on hull planking and wales on the Yenikapı ships YK 1, 5, and 11, and on the hull planking of Tantura A (Wachsmann et al. 1997, 6; Kahanov et al. 2004, 118). Steffy noted evidence for charring on the inner faces of hull planking of the Kyrenia ship, but suggests it could have also been done to drive out termites from the wood or for some other reason yet to be determined (Steffy 1999, 403).

[331] The extent to which this method was utilized during construction on YK 14 is not always obvious, due to the darkening of the wood in some areas after exposure, but it was clearly used on the wale and on several of the planks. It is also important to distinguish between charring for bending purposes and those resulting from accidental or natural charring of timbers from forest fires, accidental contact with fire around the construction site, and fire aboard ship. Some localized scorched areas on the surfaces of the frames and planking could be natural or from an episode of pitching the hull's interior rather than deliberate charring for construction purposes.

[332] Steffy describes small areas (maximum 30 cm long) of charring on the inner faces of the Kyrenia ship's hull planking, and notes that the charred surfaces were often adzed away on that vessel as well (Steffy 1985a, 84).

Figure 3.76: Strakes SS 2 and SS 3 at the aft end of the hull. Note the blackened surface on SS 3 (the upper plank in the photo), compared to the lower plank, SS 2; this is due to charring of the plank in order to bend the plank for fastening to the endpost.

Figure 3.77: Plank SS 1-3 showing charring with saw marks and a depression most likely cut with an adze removed the charred surface.

Table 3.7: Tool Marks and Other Surface Features on the Inner Faces of Hull Planking[333]:

Timber No:	Saw Mark Locations:	Adze Mark Locations:	Charring/ Possible Charring Locations:	Score Marks/ Adzed Depressions at Frame Locations:	Notes:
Starboard Planking					
SS 7-1	Across inner face	FL 17-19, along upper edge FL 19-22	-	-	
SS 7-2	None found on inner face	FL 24-28, 30-41	-	Score Marks: FL 24 (forward face edge); FL 26 (both edges); FL 29 (forward face edge); FL 32 (aft face edge); FL 34 (forward face edge-- possible); FL 40 (aft face edge)	Well preserved saw marks on outer face—FL 32, 35-40 area; adzing on aft scarf end on outer face
SS 6-1	FL 8-19	FL 9-11, 14-15 (outboard half of plank); FL 20-24 (across plank)	-	Score Marks: FL 16 (both edges, found under pitch); FL 22 (both edges)	Saw marks on OF—FL 23 area
SS 6-2/1-1A	-	Across inner face	-	FL 26 (aft face edge)	Adze marks preserved on outer face
SS 6-2A (REPAIR)	FL 27-28, 28-30	FL 27-28, 31-32, aft end	-	-	
SS 6-3	FL 45 area	FL 33-34, 38-9, 41-43	FL 46-7 (probable)	-	Poor tool mark preservation.
SS 5-1	-	Across inner face	-	Score Marks: FL 12 (forward face edge); FL 16 (both edges, found under pitch)	

[333] This category does not include score marks at coak positions or score marks on repair pieces.

Table 3.7, Continued

Timber No:	Saw Mark Locations:	Adze Mark Locations:	Charring/ Possible Charring Locations:	Score Marks/ Adzed Depressions at Frame Locations:	Notes:
SS 5-2	FL 19-29 (outboard half of plank)	FL 18-25, 28-29 (inboard half of plank),	-	-	Well preserved tool marks
SS 5-2A (REPAIR)	-	Across inner face	-	-	
SS 4-1	Across inner face—FL 7-11, 13-14, 18-19, 21-26, 29-aft end	FL 7-8, 11-12, 15-19, 27-29	FL 7-10, 18-20, 21-22, 23-25	-	Good tool mark preservation. Blackened areas "probably sulfide staining"
SS 4-2	Poss. between FL 33-34 (OR wear marks)	All of inner face except FL 33-34	-	Score Marks: FL 33 (aft face edge)	Score mark possibly for nearby coak, but is closer to the frame location
SS 3-1	FL 13-15, 20-21, 24-25	FL 5-7, 9-11, 15-17, 18-19	FL 2-3, 8-9, 12-13, 15-16	-	Clear burnt areas
SS 3-2	FL 32-35	FL 27-32, FL 35-41	-	-	
SS 2-1	FL 2-6, 7-14, 16-20	Aft hood end, FL 7-8, 9-11	FL 3-5, FL 7 area, small spot between FL 18-19	-	Well-preserved tool marks
SS 2-2	FL 35-39, FL 43-45 (small sections), FL 46-47 (between adzed areas)	Aft scarf (FL 21-22), FL 24-25, FL 39-46, FL 46-47 (between sawn areas)	FL 24-25, 27-28 (possible); FL 46-47 (small patches)	-	No clear tool marks between FL 33-35 (sump area?) FL 25-32 (worn?)
SS 1-1/1	None found	Adzed across inner and outer faces	-	-	Well preserved tool marks

Table 3.7. Continued

Timber No:	Saw Mark Locations:	Adze Mark Locations:	Charring/ Possible Charring Locations:	Score Marks/ Adzed Depressions at Frame Locations:	Notes:
SS 1-1/1A-5	None found	Adzed across inner face	Between FL 17-18—18 cm long, 9.5 cm wide section	-	
SS 1-2	FL 26-38	FL 26-27, 27-28, 29-30 (outboard half)	FL 34-35, 35-36, 36-37 (probable burnt spots)	-	Well preserved tool marks, mostly sawn. Some saw marks visible on OF
SS 1-3	FL 38-42; FL 43-4 (inboard half of plank); FL 44-45; FL 46-7 (outboard half); FL 48-51)	Between FL 38-40, at FL 42, FL 42-43 (most of inner face/charred area), FL 43-44 (?); FL 45-46 (inboard area), FL 46-48 (in non-charred areas); FL 48-49 (isolated adze marks)	FL 40-42 (small patches, possibly burned); 42-49. Clearest between FL 42-4, FL 45-7.	Adzed depression at FL 42 floor location.	Clear tool marks and charring. Some charred areas adzed away (most clearly between FL 46-48; possibly between FL 43-44). Possible 'saw return marks' on inner face between FL 38-40
Port Planking					
PS 1-1	-	Inner face	-	-	
PS 1-2	Inner face	Inner face (inboard edge)	-	Score Marks: FL 46 (aft face edge)	Saw marks angled in two directions between FL 36-39
PS 2-1/1-2 (REPAIR)	-	Inner face	-	-	
PS 2-1/3	FL 8-9	Inner face (inboard, outboard edges)	-	-	Worn inner face surfaces

Table 3.7, Continued

Timber No:	Saw Mark Locations:	Adze Mark Locations:	Charring/ Possible Charring Locations:	Score Marks/ Adzed Depressions at Frame Locations:	Notes:
PS 2-1/4-6A	FL 12-13, 14-15, 18-21,	Upper, keel edges; Inner face between FL 16-17	-	-	Mostly sawn—well preserved tool marks
PS 2-2	FL 20-31	FL 20, between FL 20-21, 24-25, FL 25-28, 31-2, 35-42 (inboard section of plank); most of FL 42-forward end	-	Score Marks: FL 40 (both edges); Adzed depression at FL 20	Adze marks visible on outer face—FL 20-21, 23-24
PS 3-1	FL 3-5, parts of FL 9-11, 13-14; FL 16-20; on aft scarf	FL 2-7 (outboard section of plank); FL 6-8, part of FL 9-10, FL 10-13, 14-15, most of FL 20-23 surface	FL 2-6 (except for adzed area near outboard edge); FL 9-10; spots between FL 10-11; parts of area between FL 13-15, 15-19, 20-21	-	Adzing done after charring
PS 3-1A (REPAIR)	-	Inner face	-	-	
PS 3-2	FL 30-31 (part of surface), 31-32, 33-36	FL 25-29, 30-32, 36 to aft end	FL 30-32 (charred??), 38-42 (charred)	Score Mark: FL 38 (aft face edge, 2 possible score marks in a ‘V’ shape)	
PS 4-1	Forward end to FL 5	Some areas of edges	-	-	
PS 4-2	FL 30-32	FL 29-30 (mostly on inboard half of plank)	-	-	

Table 3.7, Continued

Timber No:	Saw Mark Locations:	Adze Mark Locations:	Charring/ Possible Charring Locations:	Score Marks/ Adzed Depressions at Frame Locations:	Notes:
PS 4-3 (REPAIR)	FL 35-36	FL 34-35	-	-	
PS 4-4	-	FL 36-38	-	-	
PS 5	Aft end to FL 15, FL 15-19, 25-30, 31-32	FL 26-28, on PS 5/3-3A	-	-	
PS 5-2 (REPAIR)	-	Inner face	-	-	Poor tool mark preservation
PS 5A/1-1A (REPAIR)	FL 19-21	-	-	-	Poor tool mark preservation
PS 5A/2-4	FL 26 area		-	-	Poor tool mark preservation
PS 6-1	FL 5-7, 9-15, FL 21-22, FL 23-forward end	FL 18-20, 22-24, elsewhere on Inner face edges	-	Score Marks: FL 7 (both edges); FL 15 (aft face edge); FL 21 (forward face edge)	
PS 6-2/1 (REPAIR)	-	Inner face	-	-	
PS 6-2/2-4 (REPAIR)	FL 26-31	FL 29-30 area (possible adzed depression)	-	-	
PS 6-3	FL 45-50	Not preserved	Probable burnt areas: Between FL 35-37, 38-39, 42-43, 44-45 (small sections); FL 45 (near upper edge); FL 47-48	Score Marks: FL 40 (aft face edge)	Poor tool mark preservation
PS 7-1	FL 12-19, 22-23	FL 10-11, 17-19, 20-22 (upper edge)	-	Score Marks: FL 23 (both edges)	Saw marks on outer face in aft scarf area

Table 3.7, Continued

Timber No:	Saw Mark Locations:	Adze Mark Locations:	Charring/ Possible Charring Locations:	Score Marks/ Adzed Depressions at Frame Locations:	Notes:
PS 7-2	FL 25-28	FL 25-28, FL 40 area	-	Score Marks: FL 27 (aft face edge—short cut marks/possible score marks); FL 29 (forward face edge)	Poor tool mark preservation
PS 7-3	FL 45-46	Inner face	-	-	
PS 8-1	FL 13-14 (inboard edge)	Inner face	-	-	
PS 8-2	FL 15-18, 19-20, 22-23 (small section at upper edge), 23-25, 30-31	FL 18-19, 20-24, 25-29, 28-35	-	Score Marks: FL 25 (both edges); FL 30 (forward face edge); FL 33 (aft face edge)	
PS 8-3	FL 36-37 area (faint)	Most of Inner face	-	-	
PS 9-1	?	?	-	-	Poor tool mark preservation
PS 9-2/1-4	FR 19-20, 23-24, 26-29	FL 20-23, (outboard edge); FL 23-24 (inboard edge) FL 24-34	-	-	
PS 9-2/5 (REPAIR)	-	Inner face	-	-	
PS 9A	-	Inner face	-	-	
PS 9-3	FL 37-46 (mostly central section)	Most of inner face, edges	-	-	
PS 10-1	FR 20-23	FR 19-20, 24-25	FR 24-25 (20 cm—probable charring)	-	

Table 3.7, Continued

Timber No:	Saw Mark Locations:	Adze Mark Locations:	Charring/ Possible Charring Locations:	Score Marks/ Adzed Depressions at Frame Locations:	Notes:
PS 10-2	AFT end to FL 25-26, parts of FR 27-29, FR 33-36	FR 26-28 (center); FR 29-30 (outboard edge, center) 31-32, 33-35, FL 37-40	-	-	
PS 10A	FR 39-40 (small section); FR 40-43 (outboard half/outboard edge); FR 44-46	AFT end to FL 40; FL 40-43 (inboard half); FR 43-5 (most of Inner face, except outboard edge)	Between FR 41-42	-	Clear charring between FR 41-42
PS 10B	Between FR 42-43; 46-47	AFT end to FL 42; FR 42-43 (part of plank); FR 43-44; FR 45-46 (central section of plank)	Between FR 42-43; FR 46-47	Adzed depression at FL 44	Clear charring
PS 11-1	FR 17-18, 22-25, at F 29, FL 30-aft end	FR 12-13, 19-20, 25-29	Between FR 17-18 (well preserved); at FL 20 (possible)	Score Mark: F 17 (aft face edge; possible score mark)	Poor tool mark preservation forward of FL 12

Table 3.7, Continued

Timber No:	Saw Mark Locations:	Adze Mark Locations:	Charring/ Possible Charring Locations:	Score Marks/ Adzed Depressions at Frame Locations:	Notes:
PS 11-2/1-5	FR 32-38, FR 38-41 (central section of plank)	AFT scarf; FR 32-37 (along inboard edge); FR 38-41 (concentrated around edges/seams); F 41 to forward end	FR 38-39, 40-41 (found under pitch)	-	
PS 11-2/6 (REPAIR)	-	Inner face	-	-	Faint tool marks
PS 12-1	-	Inner face	-	-	Well preserved adze marks, no visible saw marks (best between FR 23-27, 29-33)
PS 12-2	FL 35-38, 38-39; in burnt areas between FR 39-42	AFT end to F 35, FR 35-36 (center of plank), FR 36-37 (sections), most of surface between FL 38-forward end	Between FR 39-40, 40-41, 41-42	-	
PS 12-3	-	Across Inner face	-	-	
PS 12A	-	FR 39-41	FR 39-40 (probable)	-	Poor tool mark preservation
PS 13/ WALE 1	FR 13-16, FR 19 (small area), FR 20-21, 22-23, 26-28	FR 17-18, 18-20, 22-28 (most tool marks on upper half of Inner face); 28-38 (all of Inner face)	Upper edge/outboard part of inner face	Adzed depressions at FL 30, 32, 34, 36. Cut/raised areas at F 17, FL 18, F 19, FL 20	Blackened areas across much of IF, but much of it is likely sulfide staining. Charring along upper edge is much clearer

Table 3.7, Continued

Timber No:	Saw Mark Locations:	Adze Mark Locations:	Charring/ Possible Charring Locations:	Score Marks/ Adzed Depressions at Frame Locations:	Notes:
PS 14-1	FL 13-15 (faint), FL 16-18	Raised cut areas at FR 11, 12, 14; some adze marks visible between FL 12-18. Slight cut depression at F 17	-	Score Marks: FL 12, forward face; between FL 16-17 (close to FL 17). Cut/raised areas at FL 12, 14	Poor tool mark preservation
PS 14-2/1	-	Adzed across Inner face (faint)	-	-	Poor tool mark preservation
PS 14-2/2-6	FR 19-31, 33-35	FR 19-20, 26-27, 30-31, 33-34 "in isolated areas"	-	Score Mark: FL 28, (aft face edge), F 29 (both edges) (possible score marks).	Mostly sawn. Blackened surface in many areas, but probably sulfide staining

Plank Edge Beveling

The inboard and outboard edges of the hull planks in most areas were clearly shaped with adzes. Adze marks were visible on many of the edges that were freshly exposed during the dismantling of the hull (**Figure 3.78**). In a few instances, a saw appears to have been used to shape straight diagonal scarf edges, such as the on the forward scarf of PS 2-2. The shaping of the edges frequently resulted in edge beveling, usually 0.1-0.5 cm in most areas, and often with the bevel reversing orientation on the same edge in different areas. Some of this beveling is probably accidental, a result of small variations in the angle of the adze used to shape the plank's edge, but in other areas the plank beveling appears deliberate. Besides the pronounced beveling of the inboard edges of the garboards and the hood ends of strakes, the bevels were cut very carefully on nearly all of the original scarf seams to ensure a tight fit. The edges of strakes below the turn of the bilge in the lower hull were generally cut to be perpendicular to the inner and outer faces of the hull planking. More pronounced beveling was evident on the ends of these strakes where they met the turn of the bilge, as on the forward ends of PS 2-2 and SS 2-2; here, the outboard edges were consistently cut with 0.4-0.6 cm-wide bevels sloping from the outer to the inner face.

Figure 3.78: Well-preserved adze marks visible on the inboard surface of hull plank PS 8-3.

Overall, the edge beveling of the planks was carefully executed, although the presence of caulking in the plank seams allowed the builders some flexibility in the construction and some leeway in shaping the plank edges. Natural curvatures are also apparent on some planks, where the sapwood was exposed on the edge of a cut plank and only the bark was removed.

Fastener Holes

Most fasteners and fastener holes in the hull planking were matched to frames removed from the hull, or were from the fastening of floors or futtocks that were lost during the ship's sinking. Generally, one or two treenails were used to fasten a frame to the hull planking at each strake, depending on the plank's width. If more than two fasteners (treenails or nails) are present on a plank, they are usually accompanied by evidence suggesting that the extra fasteners are repairs. Nails were used sparingly to fasten frames to planking at the keel and garboards, at the turn of the bilge, and at the ends of diagonal or 'S' scarfs; they were also used as edge fasteners in securing the garboards to the keel and on planking hood ends. Additional fasteners and fastener holes whose purposes were not always clear were also found in the hull planking. Unused fastener holes on repair planks are usually evidence of the previous use of a plank in another vessel hull, before they were salvaged and modified as repairs to damaged areas in YK 14's hull (**Figure 3.79**). Such fastener holes include nails, drilled holes, cut treenails, and coaks. In many cases, these features were pitched over, or the fastener hole itself was filled with pitch or caulking.

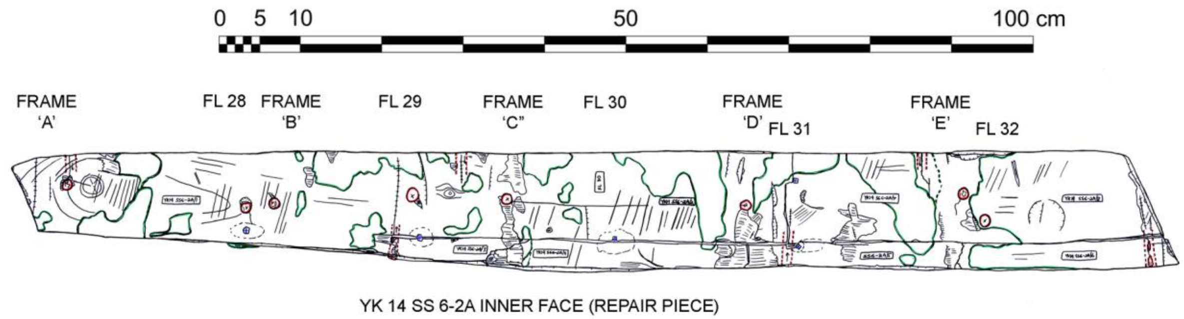

Figure 3.79: Fastener holes in repair plank SS 6-2A. The frame locations marked with letters (A-E) are from the original use of the plank, while the numbered frame locations indicate the positions of frames in YK 14. All of the fastener holes at frame locations from the plank's original use were found to be cut or filled with pitch and caulking.

Rows of fastener holes in the upper planking of the starboard side were found regularly spaced between every fourth or fifth frame. These fasteners were almost certainly used for securing second futtocks or top timbers. The largest groups consist of three or four fastener holes and occur between frames FR 11-12, 15-16, 20-21, 24-25, and 29-30, while smaller groups also occur between FR 30-31, 32-33, 36-37, 39-40, 43-44, and 44-45. The lower ends of these timbers were installed between PS 8 and PS 10; they extended at least to PS 14, and most likely to the caprail.

Other fastener holes appear to be intended for coaks or as pilot holes for nails, a common feature at the hood ends of planks and the inboard edges of the garboards (**Figure 3.80**). Still others may have been from the fastening of temporary cleats or props to the hull during construction. One set of caulked drilled holes runs from planks SS 6-3, SS 2-2, SS 1-3, PS 1-2, PS 2-2, and PS 7-2 at FL 45. These fastener holes, occurring near the forward end of the hull, are in a suitable location for securing temporary frames or cleats. Other fasteners such as the nail hole under FL 44 and a caulked hole in PS 10B, could have had similar functions. Some fastener holes could also simply be accidental or evidence of a change of plans during the construction of the hull.

Figure 3.80: An angled, caulked hole in the keel edge of garboard plank SS 1-2. This hole was likely intended for a coak or garboard nail but was not used.

Pitch Coatings on the Hull Planking

The planking in the surviving hull was originally covered with a layer of pitch both on the inside and the outside of the hull. Pitch deposits found on the hull planks during the excavation and noted during cataloging ranged in thickness from light brown stains on surfaces to deposits of a few millimeters to up to 1.2 cm thick at the pitch 'ridges' at frame edges. A well-preserved, typical pitch coating was 0.1-0.2 cm in thickness on the inner faces of the hull planks. A lack of pitch in some localized areas, along with the occurrence of fasteners in the planking, seems to indicate the locations of missing top timbers. Examples of these features are seen at PS 11-2 and PS 12-2 between FR 36-37, between FR 30-31 at PS 12-1, and on PS 12-2 between FR 40-41.

Wood-Rot Damage

Certain areas of the hull were damaged from wood rot. This damage most frequently occurred under frame locations, particularly in the space between drilled treenail holes in the planking and the treenails themselves (**Figures 3.81-3**). Both the frames and the planking were affected in many areas, often severely; in some areas, the treenail or coak had been destroyed and was no longer functioned as an effective fastener. Damage was particularly severe towards the ends of the ship, especially in the bow on strakes PS 6-10. The lack of pitch under most of the frame locations indicates that the hull planking was probably not pitched before the insertion of the frames.

Figure 3.81: An example of repaired dry rot damage on the PS 3/PS 4 plank seam under FL 10.

Figure 3.82: A rotted-out treenail under FL 40 on PS 10B seems to have been covered over with pitch.


Figure 3.83: An example of severe dry rot to the outer face of a frame timber (FL 38).

Pitch was found on a number of hull planks under individual frame locations, often mixed with sand and organic debris, with a consistency not generally seen in the pitch between the frame spaces. This was likely due to small gaps between the frames and planking, perhaps opened over time by the working of the ship and loosening of frame fasteners. In a few frame locations, caulking and pitch were clearly applied around or under a frame to stop leakage from a rotten area or loosened fastener around a fastener hole; in many cases, rotten areas under frames were partly pitched over. In the case of repair plank PS 9-2/5, an attempt to stop leakage from a longitudinal crack in the plank at a treenail hole involved driving caulking into the gap between the plank and the frame around a treenail. It is possible that pitch was applied to the outer faces of the frames before they were installed in the hull, but if this were the case, very little of the original deposits has survived. Significant dry rot damage occurred along some plank seams as well, particularly under frame locations, and was repaired with plugs of caulking made of pitch mixed with grass or hair. In particularly severe cases, areas damaged by wood rot were cut away and patched with repair planks or graving pieces ranging in length from approximately 30 to 110 cm long. Several of the 12 repair planks identified in YK 14's hull are clearly for 'patching up' rotten areas of the hull planking, particularly on narrow planks or scarf ends.

The rot damage observed at the junctions of planks and frames seems to resemble that caused by brown rot (*Serpula lacrymans*), sometimes known as dry rot. Brown-rot fungi can cause a considerable loss in the structural strength of timbers before observable surface damage to the timber occurs; the interior of timbers damaged by brown rot are reduced to cubical wood fragments.[334] Damage matching this description was found on frames FL 8, 9, 38, and F 41, and severely affected a number of planks in the hull, particularly strakes PS 6-10 in the starboard bow area. In contrast to the rot damage to the hull, very little damage from marine borers was observed; most of the teredo worm damage present in the hull occurs in the upper-most timbers of the hull, and seems to have occurred after sinking. The liberal use of pitch on the outside of the hull, perhaps combined with frequent beaching and maintenance of the vessel, may have prevented teredo infestation.

[334] Blanchette 2000, 191. After examining photographs of damage on YK 14's hull timbers, Robert Blanchette of the University of Minnesota's Department of Forest Pathology stated that the damage could have been caused by brown rot or soft rot fungi (which can occur in salt water), but that the cause of the damage cannot be confirmed without microscopic examination of wood samples (R. Blanchette, personal communication, February 19, 2013). See also Schweingruber (2007, 239-44) for a description of damage to wood from brown rot and soft rot.

Edge-Fasteners in the Hull:

Keel/Garboard Edge Fasteners

The garboards were edge-fastened to the keel with coaks supplemented by nails. Holes for the coaks were drilled from the outer face of the garboard planks, diagonally through the garboard, to the inner face, so that the inboard edge—which was beveled for most of the length of the hull—was fastened in the keel rabbet (**Figure 3.84**). The keel-garboard coaks were of similar lengths to those used on other plank seams, but tended to have slightly larger diameters of 1.3 to 1.7 cm on the keel-garboard seam and up to 1.9 to 2.1 cm on the outer faces of the garboards; the larger coak diameters on the outer faces of the garboard strake indicate that they were driven from outside of the hull. The coaks were driven upward and then the excess length was cut off, leaving ovoid sections of the coaks visible on the inner faces of the keel timbers (**Figure 3.85**). The coak spacing on the port and starboard faces of the keel timbers ranged from a few centimeters to as much as 1.17 m in one section of the keel-garboard plank seam on the starboard side. The widest spacing of coaks occurs towards the central section of the hull on Keel 2, probably due to the straightness of the keel and lack of hull curvature amidships; here the garboards did not have to be bent or twisted to edge-fasten them to the keel rabbet. Edge fasteners were more closely spaced on Keel 3 and Keel 1, towards the ends of the hulls. Most garboard nails were driven through predrilled pilot holes in the garboards. They were most frequently used towards the aft end of the ship, particularly where hood ends from the first few strakes were fastened to the keel and posts, but were also used in some areas of the central section of the keel/garboard seam as well. A few of these fasteners may have belonged to repair planks or were used as repair fasteners, but most seem to be original, judging from the absence of coaks along long stretches of the keel-garboard seams in the central section of the hull.[335]

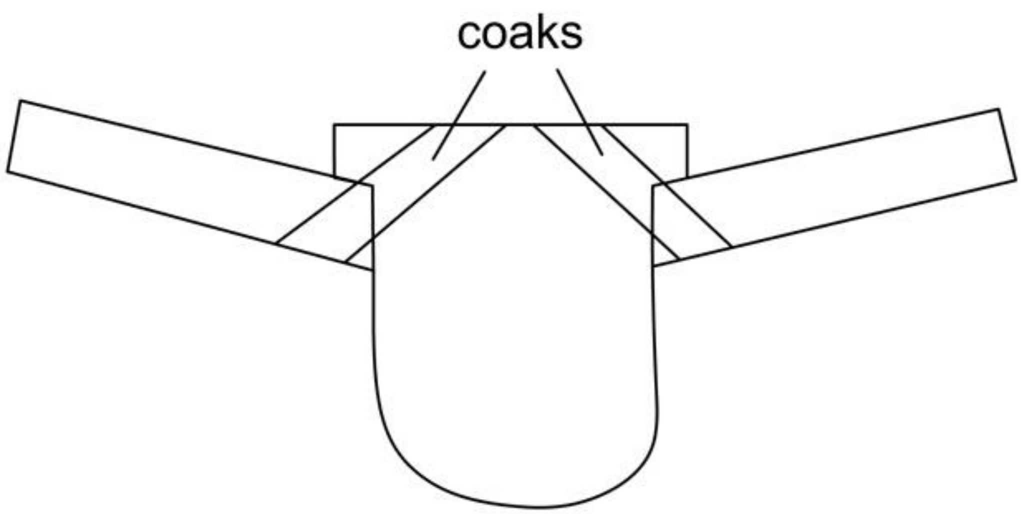

Figure 3.84: Keel cross section with the garboards fastened to its rabbets, based on the cross section of the keel and garboard strakes amidships.

[335] One definite repair nail occurs on the keel-garboard plank seam, where a nail was driven into a pilot hole from the outside of the SS 1-1/1A-5 into the outer face of FL 8. During construction, FL 8 was not nailed to the keel and had almost certainly not been placed in the hull; a coak in the SS 4/6 plank seam was placed under the location of the floor timber, which would have been extremely difficult if the floor was already in place.

Figure 3.85: Inboard ends of coaks in the keel/garboard seams .Note the cut marks on the surfaces of the fasteners.

Keel 2 was fastened to the neighboring garboards with eight coaks on the starboard side and four coaks and six to eight nails on the port face. Garboards were fastened to Keel 3 with nine coaks on the starboard face and ten coaks on the port face; no nails were used as garboard fasteners along Keel 3 on either the port or starboard side. Garboards were fastened to Keel 1 with six coaks and six nails on the starboard face; two pitched-over drilled holes whose functions are unclear were also found close to the aft end of the garboard on this face. On the port face, the garboard was fastened to Keel 1 with five coaks and ten nails, in additions to a single drilled hole filled with caulking between FL 5-6.[336]

Features of some garboard planks suggest changes or repairs made during construction. On the inboard edge of SS 1-2, drilled holes filled with caulking occur *without* corresponding fastener holes on the port face of Keel 2 between floors timbers FL 27-28, 28-29, 30-31, 33-34, and under FL 35. Additionally, one of the nail holes in the 'starboard' face of Keel 2 between floors FL 32-33 had no match on SS 1-2, and a pitched-over nail hole in SS1-2's keel edge at FL 33 had no match in Keel 2 (or FL 33). On the other hand, nails in pilot holes on SS 1-2 between FL 27-8, FL 31-2, FL 32-33 (one of two), and FL 35-36 matched fasteners on the port face of Keel 2. Similarly, on the keel-garboard seam, many coak holes and drilled holes on the inboard edges of garboard planks PS 1-1 and PS 1-2 also did not line up with fasteners; a total of ten regularly-spaced coaks on their inboard edges were not matched by fasteners or fastener holes in the keel timbers, primarily on Keel 2. It is likely that these holes were drilled beforehand into the keel edge of the garboard, and were unused and later plugged since the coaks already in place were considered sufficient for the task. Several blind fastener holes were found on other garboard planks as well.

Although drilling the fastener holes before installment of the garboards appears to be the normal practice for all of the garboard planks, several features of the port garboards are

[336] This starboard fastener appears to be within the bearding line of the garboard, based on visible damage on the keel caused by a caulking iron as well as the caulking and pitch itself.

unusual. The beveled diagonal scarf between SS 1-2 and SS 1-3 is the only original diagonal scarf of its kind used in the hull before the turn of the bilge, and one of the only original scarf ends in the hull that is not fastened with coaks. The short garboard plank SS 1-1/1, and the crudely-shaped butt scarf joint between its forward end and the next garboard plank, both suggest that extensive modifications were made during construction. This may have been due to a crack or break in one of the garboard planks, which would have required modifying the damaged piece and refastening the port garboards in a different location along the keel.

Coaks Located Above the Keel-Garboard Seams

All of the hull planks up to, but not including, the first wale were edge-fastened to each other using coaks driven into the plank edges (**Figures 3.86-8**).[337] Many coaks were carefully examined during cataloging; 33 intact examples were recovered, and others were fully exposed on the inner faces of hull planks so that their complete lengths could be measured. Hundreds of broken coaks and holes drilled for coaks in the edges of the hull planks were measured and examined during the cataloging of the timbers. Coaks show more variation in shape than treenails; they are usually round or polygonal in section, although a few with rectangular or square cross sections were also used. Some coaks have a relatively uniform diameter across the fastener, while others are thickest in the area of the plank seam or taper slightly so that the largest diameter is near the

[337] The term 'coak' is used in this report as defined in Steffy 1994, 269; see also the illustration on p. 289, Fig. G-9, (m-n). These edge fasteners are also referred to as 'dowels' in other reports; see, for example, Harpster 2005a; 2005b; Özsait-Kocabaş and Kocabaş 2008, 101-2; Pomey et al. 2012, 274, 282-84, 290.

inboard end. The tapered coaks seem to be designed so that the fastener will enter the drilled holes in the plank edges more easily, an important consideration when trying to line up multiple edge fasteners. In general, the inboard ends of many coaks are more tapered or sharpened to a pronounced point, while the outboard ends terminate in a blunt point or were cut flat. The blunter ends seem to have been deliberately faced outboard in almost every case, probably to make hammering the coak into its hole easier.[338] In other cases, the largest diameter of the coak is near the inboard end, perhaps so that the fastener lodges securely in the coak hole before the next plank is installed. The coaks range in cross section from 0.7-1.5 cm at the plank seam, but most have maximum diameters of 1.1-1.3 cm; the intact coaks recovered from the hull range in length from 7.7 to 10.8 cm. These coaks seem to be representative of those used in the rest of the hull, based on the measurements of fragmentary coaks and coak hole depths measured during cataloging of the planking. The longest coaks in the hull, such as an example at the PS 2-1/2-2 scarf, were up to 15 cm in length, and were driven through multiple scarf ends or stealers.

[338] Robin Piercy of INA was the first to note this feature of coak construction during the dismantling of YK 5. This rule seems to apply to nearly all of the coaks found during the dismantling of the hulls of YK 1, 5, 14, 23, and 24, although in a few instances the more pointed end was reversed so that they pointed outboard.

Figure 3.86: Overview of intact coaks protruding from the inboard edge of strake PS 2 during dismantling of the ship in 2007.

Figure 3.87: An intact coak protruding from the outboard edge of SS 1-1/1.

The coaks were driven into predrilled holes in the plank edges, similar in diameter to those used for the treenails fastening frames to planking; they were probably drilled using the same bow drill and drill bit or one of a similar size. The drilled holes range in depth from 1 to 3 cm at scarf tips to up to 11.5 cm in one case, but were usually drilled to depths of 5 to 8 cm. The depths of the coak holes were measured either by probing with a metal rod on a pair of calipers or by measuring the depths of coak holes at breaks. White deposits were found inside some of the coak holes and on the coaks themselves; these may be the remains of pitch or some other material used to lubricate the coaks before driving them home (**Figure 3.88**). Many coak holes were exposed at breaks in the hull planking; most were found to contain sawdust at the bottom of the hole, sometimes compressed into a rounded, hard-packed deposit in the shape of a 'cap' around the inboard end of the coak as it was driven home.

Figure 3.88: A coak exposed at a break in plank PS 2-2. Note the sawdust at the bottom of the drilled hole.

Wood samples from 29 coaks were taken during the excavation and post-excavation cataloging. The coaks showed by far the greatest variety in wood types of any wooden element from the ship's hull. The majority are Turkey oak (13, or 44.8% of the sampled coaks), nine are *Phyllirea latifolia,* a small Mediterranean evergreen tree (31%), three are European elm (*Ulmus campestris*) (10.3%), two are Sycamore maple (*Acer pseudoplatanus*) (6.8%), and one each is of Oriental beech (*Fagus orientalis)* and Italian or Mediterranean buckthorn (*Rhamnus alaternus*) (3.4% each). These results were surprising, considering that 500 sampled treenails from YK 14 were all made from the same species of oak, and the rest of the hull shows little variety in the types of wood used. Two of the wood species used in making coaks (*Rhamnus alaternus* and *Phyllirea latifolia*) were not encountered elsewhere in the eight shipwrecks documented by INA at Yenikapı (see Chapter VI).

The locations of many coaks were marked by scoring during the construction of the ship (**Figures 3.89-91**). The score marks were made with a knife or a similar sharp tool, and seem to have been intended to mark coak locations on adjacent planks so that holes drilled for the coaks could be aligned properly. The planks must have been cut to shape first, then bent and perhaps clamped into the correct position in the hull or held with temporary cleats or props. The score marks were made at fairly regular intervals when the pieces were positioned in this way, and were later separated to drill the coak holes. Approximately 177 fully or partially preserved score marks were found, often under a layer of pitch. This is a significant subset of the group of approximately 540 coaks preserved in the surviving portion hull.[339] Survival of score marks was likely affected by several factors. In some areas, the inner face surfaces of the hull planks were too soft or poorly preserved for score marks to survive, and in some coak locations transverse cracks occurred at the coak holes, often appearing to follow part or all of the length of a score mark location. In other areas, the planking may have been dubbed with adzes after assembly, obliterating score marks in the process. For these reasons, the score mark count in the hull should be considered only an approximation. However, in spite of the presence of score marks at only a fraction of the coak locations, dozens of well-preserved examples were recorded and photographed, and it seems that most, if not all, coak joints beyond the garboard strake were marked in this way during the assembly of the hull. No score marks were observed for edge fasteners on the keel/garboard seam, although the inner face surfaces of the garboards were well preserved. It appears that score marks were not necessary for marking the locations of the coaks on the keel-garboard seams.

[339] The total number of coaks cited here is an approximate count and does not include garboard nails, coaks in repair planks, caulked holes or blind fasteners occurring on only one side of an original plank seam.

Figure 3.89: Score marks indicating a coak location (the coak is marked by the three pins in plank edge at right) in a charred area of the aft end of PS 3-1. Score marks and other tool marks were often particularly well preserved in charred areas.

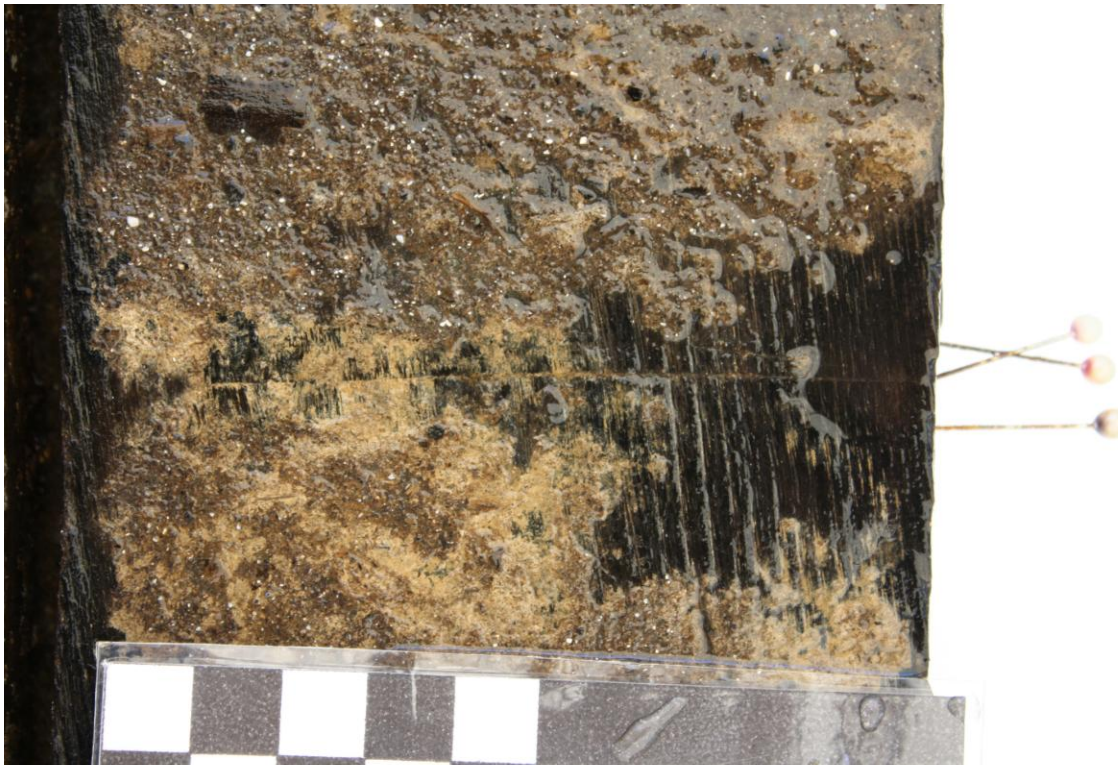

Figure 3.90: Score mark on the inner face of PS 7-3, under a pitch layer. The pins at the right mark the edges of the coak.

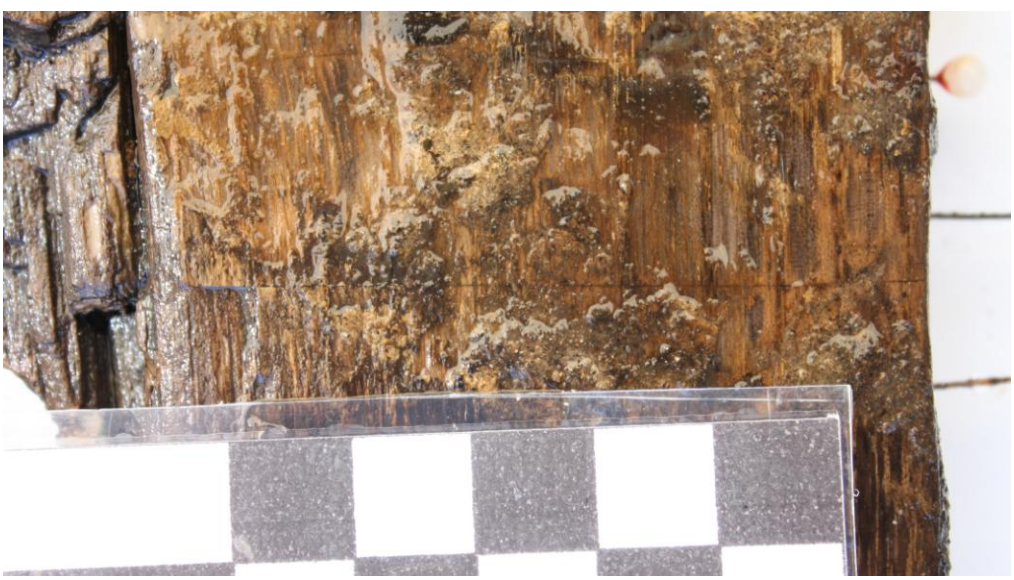

Figure 3.91: Score mark at a coak location on the inner face of PS 6-1, between FL 21-22.

The depth to which a coak was driven can often be discerned by the presence of a pressure mark on the fastener (**Figure 3.92**). In many cases, there is also a cut from a knife or a similar sharp tool at the seam location, usually corresponding to the outboard side of the seam location (**Figure 3.93**).

Figure 3.92: Pressure mark from plank seam on an intact coak.


Figure 3.93: Knife (?) cut at the location of a plank seam on an intact coak.

In some cases, these are shallow incisions, while in others they are wide gouges, often filled with pitch or with caulking fibers forced into them. The latter coaks appear to have been heavily damaged by caulking irons, possibly from multiple caulking episodes (**Figures 3.94-8**). In all, eleven intact coaks with wide gouges on the outer-face half of the coak at the plank seam were recovered: nine were found on PS 2-PS 3-plank seam between FL 19 and FL 39, with an additional two on the PS 3-PS 4-plank seam between FL 22-24.[340] On five other coaks, cut marks or possible cut marks were observed on the outer face: two on the PS 2-PS 3-plank seam and two on the PS 3-PS 4 plank seam.[341] Similar cuts were observed on intact coaks from the tenth-century wreck YK 5, but not

[340] The outboard orientation of the gouges was recorded during the excavation.
[341] These were found on the PS 2-PS3 plank seam between FL 29-30 (a faint possible cut mark) and between FL 32-33 (a cut or pressure mark). On the PS 3-PS 4 plank seam, these were found between FL 16-17 (a cut or pressure mark) and between FL 26-27 (a clear cut mark). On the PS 7-PS 8-seam, an intact coak removed from under FL 47 also had a clear cut mark.

the larger gouges corresponding to the plank seams, perhaps because it was a much newer ship and had not required major re-caulking before it sank.[342] It is likely that other examples existed, but the majority of coaks were broken during dismantling, usually at the plank seam. Nonetheless, it seems that only a few of the coaks were significantly damaged by the use of caulking irons along the plank seams. Perhaps the caulkers were reluctant to risk damaging the coaks, and usually repaired leaking plank seams using other methods, such as the heavy application of pitch from the inside of the hull.

Figure 3.94: An intact coak removed from the PS 2/3-plank seam from between FL 37-38. The notch in the coak's surface occurs at the location of the plank seam and was probably caused by a caulking iron. The notches faced the outboard side of the plank and retained pitch and caulking deposits in them.

[342] No repair pieces or any other evidence for repairs were found on YK 5, which was unusual for the roundships studied by the INA team at Yenikapı: all five of the other roundships, as well as one of the two galleys, had graving pieces or other evidence of repairs in the hull (Liphschitz and Pulak 2009, 166-68; see also Pulak 2007a, 208-13; Ingram and Jones 2011, 19).

Fig. 3.95: Caulking iron damage on an intact coak from the PS 2/3 plank seam under frame FL 34.

Figure 3.96: Detail of caulking iron damage on an intact coak from the PS 2/3 plank seam under frame FL 34. Note the caulking deposit in the cut from a caulking iron.

Figure 3.97: Coak from the PS 2-PS3 plank seam between FL 23-24, with caulking iron damage.

Figure 3.98: Coak from the PS 2-PS 3-plank seam between FL 23-24, after its discovery during the excavation in 2007. Note the white deposits on the inboard end of the coak at left in the photograph.

Some coaks show evidence of severe distortion along the plank seams; in some parts of the hull, the positions of the strakes must have shifted up to 0.5 to 1.0 cm (**Figure 3.99**). This is most dramatically shown by a distorted but complete coak from the turn of the bilge in the PS 6-PS 7 area between FL 41 and 42 (**Figure 3.100**). This type of distortion was concentrated on coaks towards the ship's extremities. Depressed areas around the edges of some coak holes in the edges of hull planks were caused by the distortion of the coaks. This feature was particularly common around the seams of strakes PS 6 through PS 12 at either end of the hull (**Figure 3.101**). That coak deformation is most pronounced towards the ends of the ship above the turn of the bilge suggests that it is due to hogging of the hull. This type of stress is inevitable in a wooden ship over time, as the ends of a hull are subject to less support from buoyancy than its central section. These features may be further evidence of the age of the vessel.[343] However, the settling of the hull planking on the seabed after the sinking of the ship could also be a contributing factor to this distortion as well.[344]

[343] Coates 2001, 153-54.
[344] C. Pulak, personal communication.

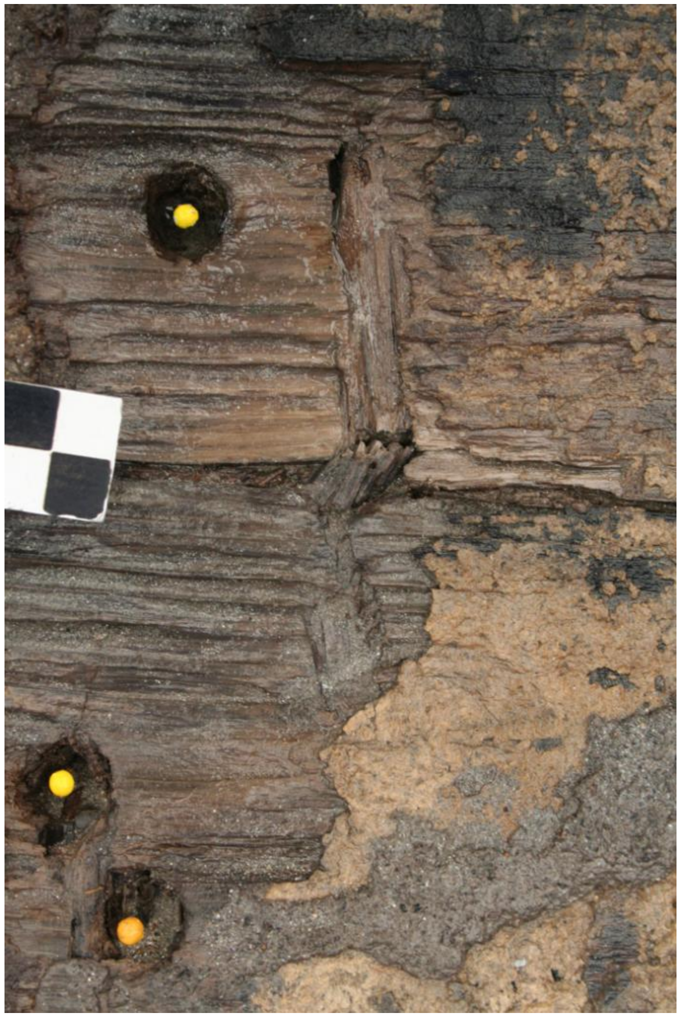

Figure 3.99: A coak distorted from shear stress and damaged by wood rot, in PS 9 and 10B, under the location of FL 47.

Figure 3.100: Intact coak from PS 6-PS 7 seam, between FL 41-42. Note the distortion of the coak at the plank seam due to hogging.

Figure 3.101: The depression around the left side of the coak hole is from shear stress distorting the coak on the PS 10/11 plank seam.

In addition to coak joints between planks, abandoned drilled holes or coaks, which had been cut off during construction, are found on some plank edges, often near a coak joint that had been used during construction. These range from shallow holes or ‘dimples’ of a few millimeters in depth to caulked holes several centimeters deep. Many of these holes appear to have been produced during the process of aligning the planks. While the planking mortises on many sixth- and seventh-century Byzantine vessels were often cut much wider than the tenons themselves, coak joints required much more precision to align the edge fasteners properly; mistakes or adjustments during positioning of the edge fasteners were probably a common occurrence.[345] In other cases, a coak hole drilled into a plank penetrated into the edge of the plank below it as well.

The distribution of coaks on plank seams is fairly regular throughout the lower hull; most coak joints are spaced between 30 and 50 cm apart. The average coak spacing along plank seams is 39.1 cm, excluding coaks at scarf ends, which at some places are driven only a few centimeters apart. Coaks are also more closely spaced towards the tapered ends of stealers and drop strakes as well. The widest coak spacing occurs in the center of the hull, particularly along the seams between the keel and garboards, where coak joints were spaced from 60 cm to 117 cm apart in some areas; such wide spacing was not found on the other strakes in the lower part of the hull. On wider planks, coaks and coak holes usually penetrated about half of the width of the plank, while on narrower planks they could be drilled through most or all of the plank’s width. Coak

[345] van Doorninck 1982, 55.

positions were usually staggered whenever possible so that locations of coaks on one seam did not align with those on the next to create a weak point. This, nonetheless, did sometimes occur; in one instance, on the PS 7-PS 8 seam, one coak was drilled through another between floors FL 33 and 34.

The turn of the bilge was one of the most difficult areas of the hull to assemble with edge-fastened planking. In this area, broken coaks were found along the plank seams appear to have been broken in antiquity, either before or during the sinking of the ship. Other complete coaks appear to have been bent during construction in areas where the turn of the bilge was particularly sharp, particularly in the forward and amidships section of the hull along the PS 6, 7, and 8 seams (**Figure 3.102**).[346] Much of the plank PS 7-2 was bent into a concave shape, another apparent sign of the mechanical stress on this area to the hull planking. Some drilled holes on the inboard sides of coak joints were angled, with the inboard ends of the coak holes emerging on the planks' outer faces; this feature was not observed in other areas of the hull planking (**Figure 3.103**).[347]

[346] As most of the coaks at the turn of the bilge on the port side (in the area of SS 4 and SS 6) were broken in antiquity, bent or distorted coaks were not observed in this area, although they may have been present in the hull when it was built. Steffy (1985a, 90) notes that, on the Kyrenia ship, some of the tenons in the mortise and tenon joints between the keel and garboard strakes were deliberately bent as well.

[347] These include the inboard ends of three coaks in PS 5A-PS 6 plank seam between FL 24-27; coaks on the PS 7-PS 8 seam between FL 41-42, the SS 6-SS 7 seam between FL 23-24, and the SS 7-SS 8 seam at FL 23. In other areas of the hull planking, the inboard end of a coak or coak hole is exposed on the inner faces of the planks, but the angling of these coaks appears to be accidental.

Figure 3.102: Coak bent at the turn of the bilge on the PS 7-PS8 plank seam.

Figure 3.103: Ends of two coaks emerging from the outer face of plank PS 5A/2-4. These coak may have been deliberately angled to compensate for the sharp turn of the bilge in this area of the hull.

Caulking of Plank Seams

Caulking was well preserved in all of the plank seams which had not separated after the ship's sinking. These deposits ran the length of the ship, an indication that the caulking was an original feature of the hull construction and not due only to later maintenance or repairs. The caulking mixture was made from a combination of pine pitch and grass used as filler, although occasionally hair was also used. Caulking in seams tended to be 0.1 to 0.5 cm thick, with 0.2-0.3 cm thick deposits being most typical in areas that had not been repaired. Often, the cross section of caulking was wedge-shaped or 'T'-shaped, with the wider sections on the outboard side of the plank edge, as if the material was forced to the outboard side of the plank edge after being compressed. On some of the uppermost seams in the hull above the turn of the bilge, particularly around the first wale, more caulking appeared to have been applied to the outside of the hull in the form of pitch, and caulking fibers were laid or driven along the plank edges. Presumably, due to the absence of edge fasteners in these plank seams and their location in the hull, the waterproofing of the plank seams could be less careful in this section of the ship than in the areas below the waterline. The caulking appears to have been molded around many of the coaks, particularly along the plank seams in the lower part of the hull; this feature suggests laid rather than driven caulking deposits similar to those seen in **Figure 3.107**. The material is usually thinnest or absent on the inboard side of the coak on a plank seam (**Figures 3.104-5**). Thinner caulking deposits are also typical of diagonal and S-scarf seams; this is not surprising since they are fastened with closely spaced coaks and are shaped for a tight fit. On some scarf seams, such as the S-scarf between PS 8-1 and PS 8-2, there was almost no caulking along the seam at all. In other sections of the hull planks, edge beveling is less precise, but any gaps in the seams were easily filled with thicker caulking.

Figure 3.104: Caulking around a coak in SS 1-SS2 plank seam. The caulking deposit shown is fairly thick but typical of those in YK 14’s plank seams.

Figure 3.105: Caulking around a coak in the upper edge of plank PS 4-2. Note that the caulking fibers surround the coak everywhere except at the inboard side of the plank edge, which is instead covered with pitch that may have leaked into the seam from inside of the hull.

There is no clear evidence on the edges of the hull planks of regular beveling or grooves cut to receive caulking—a method used to assist in the caulking of ships in later periods—although some plank edges exhibit natural or cut bevels along the edges. This seems to preclude the regular use of a reefing tool like the one found with the tool set on the Serçe Limanı ship, a standard piece of equipment in later periods for removing old caulking before driving new caulking into plank seams.[348] If such a tool were used for regular maintenance and re-caulking of the hull, one would expect wider, more consistent beveling or grooves along the plank seams and more splintering on the plank seam edges. There is also no evidence for the cutting of grooves along the plank edges similar to the luting coves cut for laid caulking in northern European lapstrake construction.[349] The most likely explanation is that most of the caulking was applied as laid-caulking during the ship's construction, a process that required little or no additional shaping of the hull planks' edges.

[348] Such tools appear to have been in use by the tenth century, based on a drawing in a manuscript of Dioscorides' *De materia medica* (Pierpont Morgan Library, Cod. 652, fol. 240r), in which two caulkers use hook-shaped tools on the hull of a ship propped on shore; Pryor and Jeffreys (2006, 150-51) interpret this activity as the removal of old caulking before re-caulking (see also Adam and Villain-Gandossi 1991, Fig. 7).
[349] Steffy 1994, 275.

However, caulking was clearly driven into at least some plank seams in the hull after the ship was built. Besides the evidence of caulking iron damage on some coaks, many rot-damaged areas in the hull were plugged with caulking and pitch, often up to 1-2 cm thick; caulking ranging from 0.3-0.7 cm up to 2.15 cm thick was also driven around repair planks. The thick caulking in some areas of the keel/garboard seams appear to be due to one or more episodes of re-caulking, based on grooves and cuts in the port and starboard faces of the keel timbers found under layers of caulking and pitch (**Table 3.8**). The missing tips of several diagonal scarfs in the planking, such as those at the forward end of PS 5A/2-4 or the aft scarf tips of PS 6-3 and PS 9-3, could have been damaged with caulking irons during re-caulking of the hull, although other explanations are possible as well (**Figure 3.106**). Caulking and pitch repairs were also made in the regions of fastener holes. Wood rot damage often concentrated around drilled holes for treenails, particularly at the bow area of the ship.[350] In addition to the damage caused by dry rot, these repairs would have been necessary due to the ‘working’ of the hull over time, which would have loosened hull fasteners.[351]

[350] The bow was also an area of significant rot and wear on the Kyrenia ship (Steffy 1999, 401). Rot damage did not concentrate around most nail holes, however, even when pilot holes were drilled from the outer to the inner face. In a few cases, nails were driven into areas damaged by wood rot, but these fasteners were likely added as later repairs.
[351] Bass et al. 2004, 165; see also McCarthy 2005, 64.

Figure 3.106: Caulking repair at the aft scarf tip of PS 9-3.

The effects of ‘creep’, or the permanent stretching of wood fibers under tension over time, as well as variations in moisture, would have also caused significant deformation to treenails similar to that seen in coaks, which, in turn, would increase leakage in the hull.[352] Such deformation is apparent on some of the intact treenails extracted from the hull during its dismantling.

352 Coates 2001, 154-55, 158, 161-62; see also McCarthy 2005, 64.

Table 3.8: Major Caulking Repairs to the Hull Planking[353]

Plank/Plank Seam:	Location in Relation to Framing:	Dimensions (cm):	Description:
SS 5-2	Between FL 22-23	7.2 x 0.45	Insect bore hole plugged with grass caulking and pitch mixture
SS 4-2	1) Between FL 32-33; 2) At FL 38	1) 3.0 x 2.0; 2) 1-2	Knot hole, plugged with hair and pitch (on inboard side; grass/pitch was found on the outer face); a crack runs from the knot towards FL 33, which was caulked with a mixture of grass and pitch 2) Caulking and wooden plug, or second treenail, at a crack in the timber
SS 3-1	Forward Hood End (FL 1-2 area)	-	Caulked crack in the forward hood end
SS 3-2	At FL 40	-	Caulked drilled hole or damaged area under frame next to treenail
Keel/PS 1 seam	Between FL 44 and 46	l. =17.5, w. = 1.1	Caulked area damaged by dry rot
PS 1/PS 2 seam	1) At FL 16-17; 2) At FL 45	1) l. = 20.0, w. = 1.3 (max.) 2) l. = 16.0, w. = 1.6 (max.)	1) Caulked split in keel edge, possibly from re-caulking 2) Caulked area under frame damaged by dry rot
PS 3/4 seam	At FL 43	4-5	Large amount of caulking, probably a repair to the scarf end
PS 4/5 seam	FL 9-10 area	21.5	Caulked area at dry rot damage
PS 5/6 seam/PS 5A/1-1A seam	Between FL 18 and 19	10	Caulked repair on seam
PS 5A/1-1A/ PS 5A/2-4 'scarf' seam	At FL 23	-	Caulked area at 'scarf' seam (rotten area at coak)
PS 5A/2-4	Forward end (between FL 28 and 29)	L.= 14; w. = 2	Caulking repair at broken scarf tip
PS 5/6 seam/ PS 6-3 forward end	At FL 32	-	Damaged scarf tip repaired with caulking

[353] This table does not include caulking repairs to fastener holes or caulking driven around repair pieces.

Table 3.8, Continued

Plank/Plank Seam:	Location in Relation to Framing:	Dimensions (cm):	Description:
PS 6-2/2-4 (REPAIR PLANK)	1) Forward of FL 27 location; 2) Caulked split down length of piece	1) 4.1 x 2.5; 2) [length of plank]	Rot-damaged area plugged with pitch and caulking; possibly on original plank or original use of this repair piece?
PS 6/7 plank seam (PS 6-1. PS 7-1)	FL 8 area (forward surviving end of PS 7-1)	21 x 1.05 (max. width)	Rotten area of seam repaired with caulking
PS 6/7 seam	FL 46-7 area	27 x 1.0	Caulking repair to rotten area on upper edge of PS 6-3
PS 7-3	Forward of FL 41	6.0	Forward tip of scarf missing; gap-filled with caulking
PS 7/8 seam	At FL 39	-	Caulking at rotten area on seam
PS 7/8 seam	At FL 46	-	Caulking at rotten area on seam
PS 8-3	At FL 37	2.1	Caulking around rotten TN hole at FL 37
PS 8-3 (2)/ PS 8/9 seam	FL 38 area	l. = 17, w. = 0.9 (max. width)	Repair to rotten area on seam
PS 8/9 plank seam (PS 8-3, PS 9-3)	FL 47-48 areas	l. = 15.0, w. = 1.0 cm	Caulking repair to rot along plank seam
PS 9-2/5	At FL 35	-	Caulking around treenail hole; probably due to a longitudinal crack in the scarf tip
PS 9-3	Between FL 34 and 35	8.0	Damaged scarf tip repaired with caulking
PS 10-2	At F 33	5-6	Caulking repairs around severe dry rot damage on plank
PS 9-3/10B seam	At FL 46	1.0	Caulking repair to rot-damaged seam under frame
PS 11/12/13 junction	At FL 20	-	At notch/bevel in outer face. Heavily caulked—source of leakage?
PS 11-2/5	1) At FL 32 2) At FL 33	-	1) Large clump of pitch at knot hole; grass/pitch caulking driven into crack along wood grain running from knot hole. 2) PS 10/11 seam: rotten area at the plank seam caulked over
PS 11-2/1-5/ PS 11-2/6 ‘scarf’ seam	At F 43	-	Heavily pitched edge of repair piece, in a rot-damaged area
PS 12-3	Between FR 43 and 44	-	Crack caulked in antiquity from the outer face

Table 3.8, Continued

Plank/Plank Seam:	Location in Relation to Framing:	Dimensions (cm):	Description:
PS 13	1) FL 14-19 area; 2) FL 23-26	1) l. = 27 cm (FL 16 area) 2) l. = 43 cm	Extensive damage from rot along lower edge of wale. Previous strakes (PS 11, 12, 12A) are barely affected. Area repaired with thick (up to 2.2 cm) pitch deposits containing small amounts of grass caulking, probably applied from outside of hull. Approximately 27 cm-long section of outer face of wale was cut away with an adze in the area of FL 16, and covered with pitch, perhaps because the area was rotten (?); or, it may have been cut off during construction to remove a branch or other irregularity in the wood
PS 14-2/2-6	1) Between FL 18 and 19; 2) Under FL 32	1) 5.2 x 3.9	1) Triangular plug made from hair and pitch in PS 14-2/2-6's missing scarf tip. The repair was made during the initial construction of the ship 2) Crack running from through-beam aperture to FL 32, repaired with caulking from outside of the hull

The cuts in intact coaks removed from PS 2-PS 3 and PS 3-PS 4 plank seams indicate that at least parts of these seams were re-caulked during the lifetime of the ship. However, several intact coaks on these seams are not marked at all, in spite of original locations between coaks with large gouges at the plank seams. Similar evidence occurs on the seam between the keel and the garboard planks as well; on large sections of the starboard face of the keel, caulking iron damage was absent. Perhaps some caulkers were more careful about damaging coaks than others, or the driving of caulking was done selectively and only in the areas with the most leakage. Evidence for marks from caulking irons may be more difficult to identify on broken coaks (which may have broken precisely at the locations damaged by re-caulking) but it appears that most of the intact and fragmentary coaks examined were not marked by caulking irons. This seems to suggest that re-caulking of plank seams was done selectively, perhaps in an attempt to avoid cutting or damaging edge fasteners, which in turn suggests that the coaks may have been perceived to play some role in the structural strength of the ship.

The orientation of the caulking fibers in the plank seams may offer some clues to the role of driven versus laid caulking, but this evidence is often ambiguous. In some areas, caulking fibers seem to be oriented perpendicular to the inboard and outboard edges of the planks. Caulking fibers driven into the grooves in the port and starboard faces of the keel timbers and in the thick caulking deposits around some of the repair planks were oriented in this way. In other areas, the fibers run more parallel to the plank edges. The seams at the wale and on some repair planks cover only the outboard half of the plank seam (**Figures 3.107-8**). It is likely that these upper seams were sealed with caulking driven from outside of the hull, since no edge fasteners were present.

Figure 3.107: Caulking on the outboard edge of a repair piece, SS 5-2A. Note the cut coak on the seam from the plank's previous use, and the concentration of the caulking on the outboard half of the plank seam.

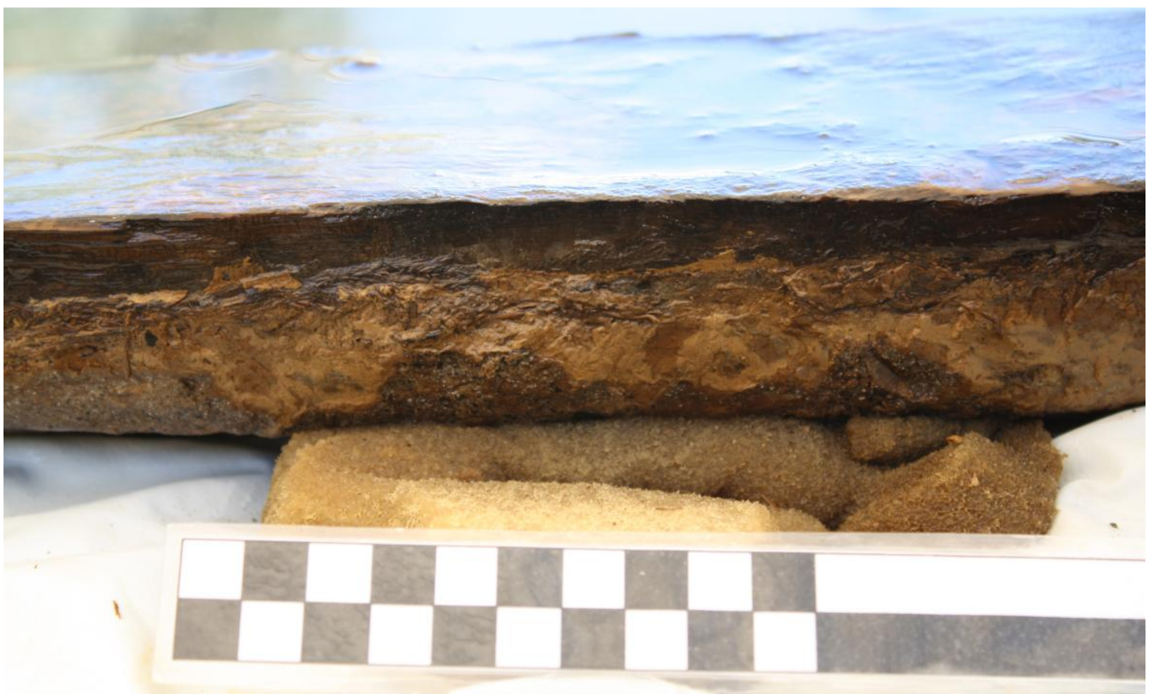

Figure 3.108: The caulking along much of PS 13 consisted of pitch with caulking fibers primarily along the outside edge of the seam.

Regardless of how the ship's plank seams were caulked, it is clear that YK 14 may have been re-caulked a number of times, in at least some areas of the hull. In later periods, ships were re-caulked on at least an annual basis, since the working of the ship often forced caulking from the plank seams over time and increased leakage in the hull.[354] Re-caulking also serves to stiffen a wooden hull structurally, allowing it to better resist shear forces.[355] On the Yenikapı ships, leakage along plank seams could have also been dealt with in other ways, however, such as the repeated application of a thick layer of pitch on the hull's inner and outer surfaces.

Removal of Bilge Water

Bilge water would have been removed from the ship using a bucket or scoop; the vessel is small enough not to have required a permanent bilge pump. Possible evidence for a bailing in some sections of the hull consists of an absence of pitch deposits combined with lateral wear marks on the inner faces of planks PS 2-2 between FL 35-37, and SS 2-2 between FL 33-35 (**Figure 3.109**). Since there appears to have been no clearly delineated sump area for bilge water in the ship, bailing may have occurred in other sections of the ship as well.

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[354] Coates 2001,154.
[355] Coates 1985, 438-41.

Figure 3.109: A worn area on plank SS 2-2, possibly used for bailing bilge water out of the hull. Striations across the width of the plank in an area without preserved pitch; the gray deposits on the plank's surface are concretion, which indicates that these striations are an old feature and were not made during the excavation.

Wale PS 13

PS 13 is the only wale timber recovered from YK 14, surviving to an approximate length of 6.91 m. The wale was cut from a single straight oak log of *Quercus cerris* and bisected with a saw; all of the faces of the timber were further worked with an adze. Flat sections were cut on the upper and lower edges of the wale to accommodate the adjoining strakes. Both ends were broken during or soon after the ship's sinking (**Figure 3.110**). The wale's width ranges from 8.0 to 10.45 cm, and its thickness ranges from 3.6 to 7.15 cm; the timber has a gradual taper, with the wider end placed towards the forward end of the hull. The original surfaces of the wale timber were found to be in very good condition, due in large part to the thick pitch layer on the outboard surface of the timber, which ranged in thickness from 0.5 cm up to 1.5 cm in most areas near the plank seam. Areas of wood-rot damage along the lower edge and outer face of the wale between frames 15-16 and frames 23-26 were repaired with generous amounts of pitch; in one area around FL 16, where a deep depression was cut into the wale (perhaps to remove a rotten area?), the pitch deposits were up to 2.3 cm thick.[356]

Charred areas of the wale are concentrated on the upper part of the inner face, small sections of the lower edge, and lower section of the inner face (**Figure 3.111**). Blackened sections of the inner face occur between FL 32-33, 15-16, and at F 27, although some of these areas could be darkening of the wood from iron sulfide staining rather than deliberate charring. Charring was also apparent on the inner faces of oak wales from other ships excavated at Yenikapı, including YK 1, 5, 11, and (possibly) 23.

[356] Steffy noted that a similarly thick layer or layers of pitch were present along the plank seams of the wales preserved on the Serçe Limanı ship (Steffy 1999, 403; see also Bass et al. 2004, 112).

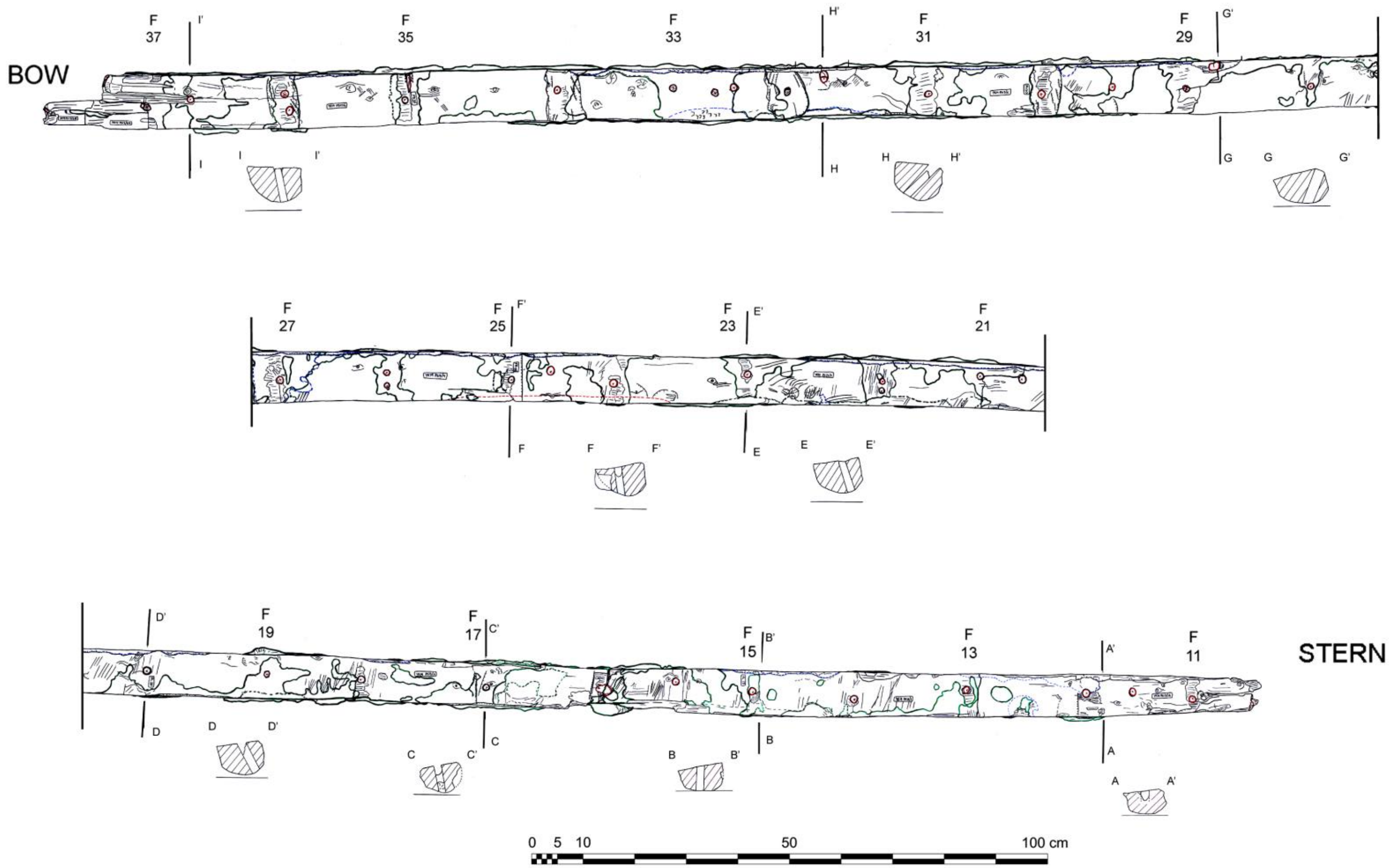

Figure 3.110: Inner face and cross sections of wale PS 13.

Figure 3.111: Charred area on wale PS 13's inner face; note the rough upper edge.

Several features of wale PS 13 indicate that it is the first timber in the outer hull planking to be installed 'frame-first'. Firstly, PS 13 is the lowest original strake in the hull without regularly spaced coaks fastening it to adjoining strakes. There is only a single coak found on the wale, which was used to fasten the diagonal aft scarf end of PS 14-2/2-6 to the upper edge of the wale (**Figure 3.112**).

Figure 3.112: The inboard half of a coak for fastening the forward scarf end of plank PS 14-2/2-6 is exposed at a futtock location on the inner face of wale PS 13. This is the only coak found driven into PS 13.

Secondly, cut depressions occur on the inner face of the wale at the locations of floors FL 36, 34, 32, and 30, while raised areas were cut at the locations of frames FL 20, F 19, FL 18, and F 17, an indication that these floor timbers were already in place when the wale was being shaped and bent around these frames in a specific way (**Figures 3.113-14**). Similar raised areas also occur on the next strake, PS 14-1, at FL 12 and FL 14. The reason for these raised areas is unclear, but may relate to an attempt to thin the wale timber to increase its flexibility while also avoiding a gap between the frames and the wale in the same area. Another possibility is that they are the result of adze dubbing on the inner surface of the planking between frame locations after the installment of the frames; if the frames were in place, the planking beneath them could not be trimmed to the same extent as the surfaces between frames. The lack of such features below PS 13 suggests that no frames were in place to obstruct such adze dubbing below the first wale.

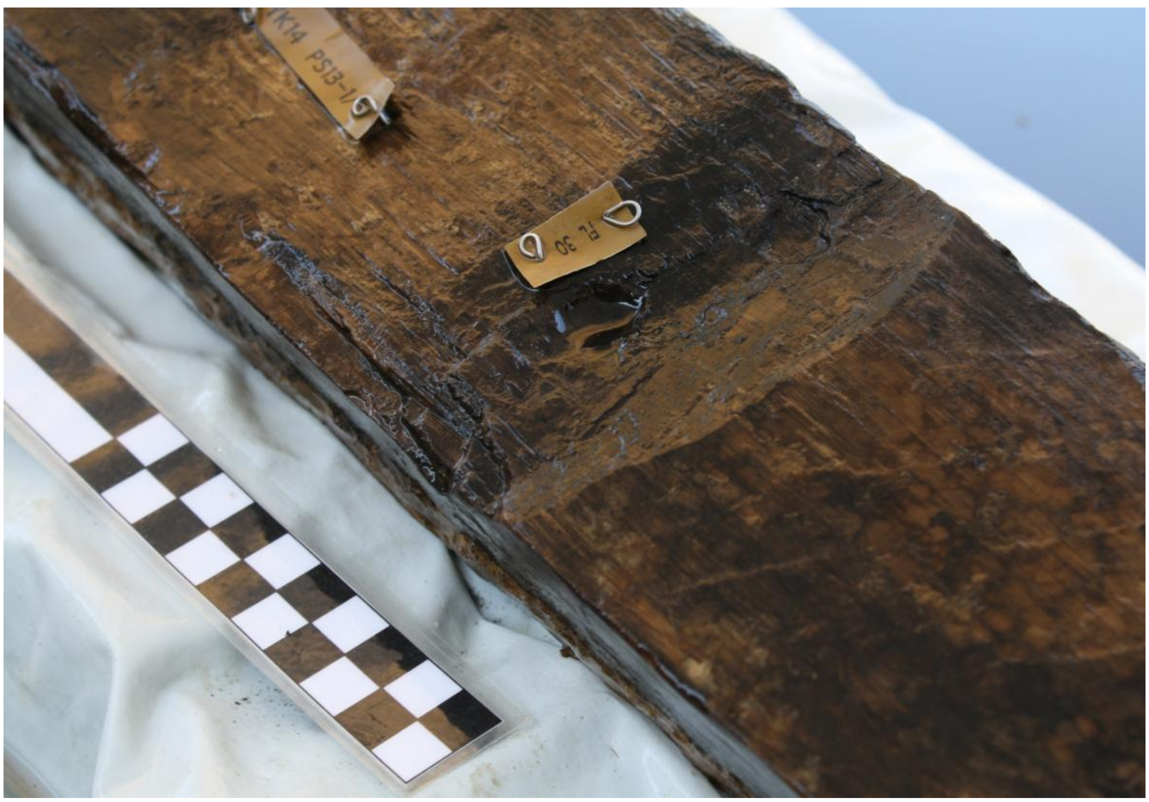

Figure 3.113: Cut depression at FL 30 frame location on PS 13.

Figure 3.114: A cut at a raised area on PS 13 at the location of F 17.

Thirdly, on the upper edges of strakes PS 12 and PS 12A, directly below the wale, small, caulked-over notches were cut adjacent to thirteen floor timbers at FL 12, 14, 16, 18, 20, 22, 24, 26, 28, 30, 32, 34, and 36 (**Figures 3.115-17**). The notches are 0.3-1.0 cm deep, and are spaced between 41.8 and 56.2 apart, center to center, with an average spacing of 46.9 cm; however, the spacing varied sufficiently to suggest that they were not positioned precisely using a specific length standard. The widest and deepest parts of the notches are along the outboard edge of the hull planks. Tool marks were clearly evident in the notches, so there was no question of their being a result of rot or other damage. Their average maximum depth is 0.6 cm, although several were cut up to 0.7-1.0 cm deep. Each notch had been filled with pitch and caulking. The notches vary in shape, but most are roughly triangular or trapezoidal, and were likely cut with an adze or chisel.

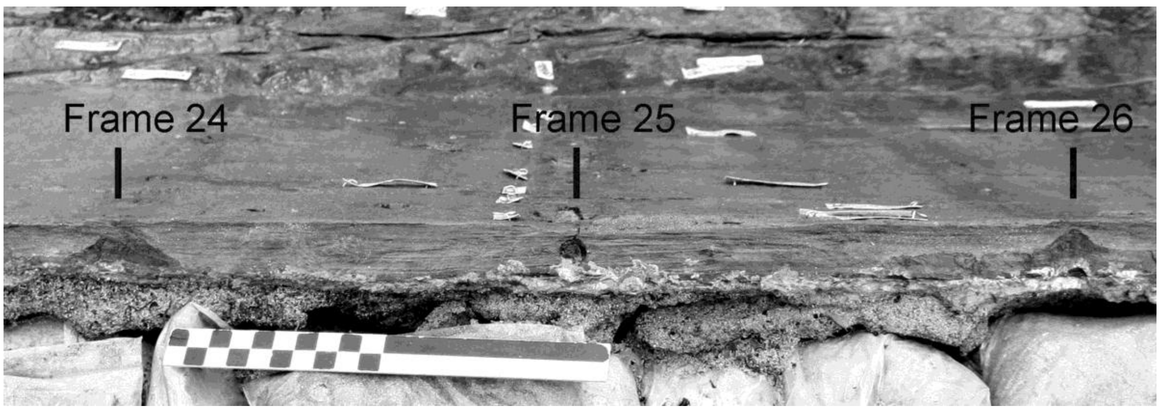

Figure 3.115: Two of the notches in the upper edge of the planking below wale PS 13 corresponding to the locations of frames FL 24 and 26. The darker stains on the inner faces of the hull planks are frame positions.

Figure 3.116: Detail of the notch in the upper edge of PS 12-1 at the location of FL 26. Note the caulking adhering to the surfaces of the notch.

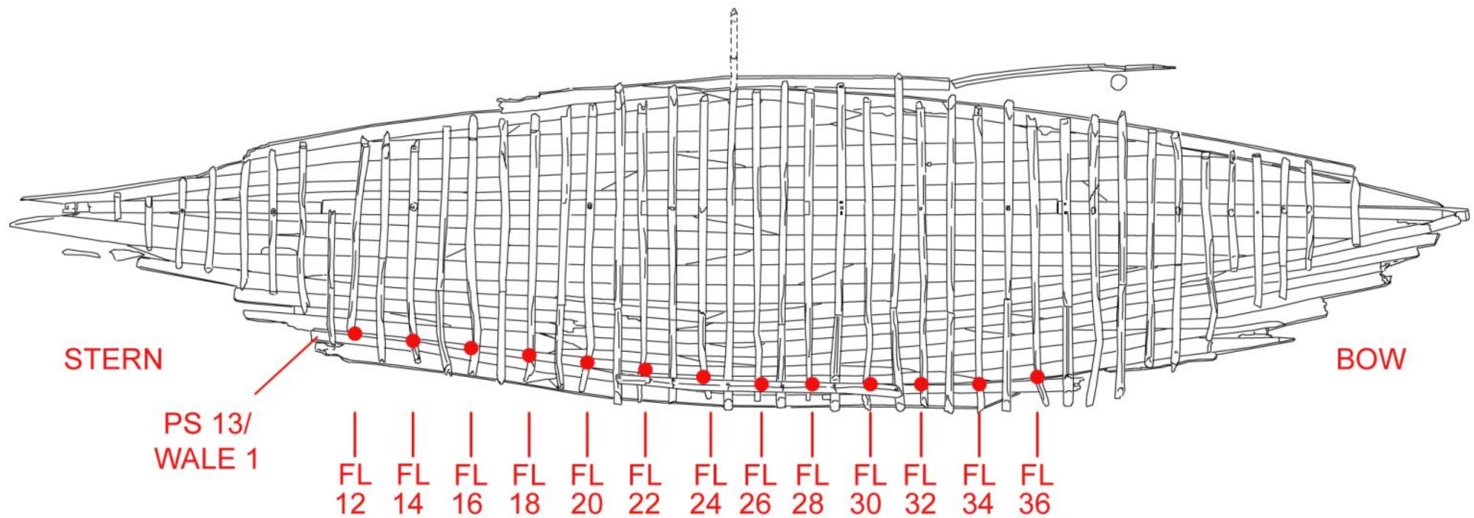

Figure 3.117: The locations of notches in the planking under wale PS 13 corresponding to the locations of ‘long arms’ of floors.

Glenn Grieco, the ship-model builder at the Center of Marine Archaeology and Conservation (CMAC) at Texas A&M University, discovered the probable source of these cuts during the construction of a research model with Cemal Pulak of the tenth-century Yenikapı galley YK 4. Several frames had been installed on the model to keep the hull planking together. While shaping the upper surface of the strake in preparation for installing the first wale, he found that he was unable to cut down the plank at the locations of the pre-erected frames except with a chisel, producing cuts in the upper edge of the plank similar to notches found on the upper edges of hull planks on YK 4.[357] The notches on the upper edges of planks PS 11-1 and PS 12-1 on YK 14 are very similar to those on the YK 4 planks, differing from the YK 14 examples primarily in that they are much more closely-spaced. On YK 14, the notches occur only at the 'long arm' ends of floor timbers in the main body of the hull.

This explanation for the notches in YK 4's plank edges also explains these features on YK 14. As the wale was not fastened with coaks to the hull planks below it—an operation that would have been extremely difficult to perform due to the rigidity of the wale—some sort of framing, either temporary or permanent, was required in the hull at this stage. YK 14's builders chose to install the floor timbers in the main body of the hull at this time, perhaps in addition to frames at the ends of the hull as well, although these

[357] The orientation of the triangular notches on the YK 4 planking was reversed, however: the widest part of the notch occurs on the inboard side of the plank edge. The reason for this difference is unclear, but may be the result of a different technique for shaping the notches, or simply that the notches were cut with the same tools but from different angles.

have not survived. The long arm ends of the floor timbers terminate at PS 14 or PS 15, so they could have been used as a framework for installing at least two or three strakes.

Locations of Through-beams on Wale PS 13

Although the actual timbers did not survive, evidence from the wale and the next strake above reveal the locations of at least two through-beams (**Figure 3.118**). Both rested on the upper face of PS 13—one just aft of the grooved futtock F 29 and the other just aft of the grooved futtock F 32—and were fastened to the wale with treenails driven diagonally downward through drilled holes 1.8-2.1 cm in diameter (**Figure 3.119**). No corrosion products from metal fasteners were found in either of the holes, indicating that metal fasteners were not used to secure the timbers; however, a treenail fragment 6.2 cm long and 1.2-1.3 cm in diameter was found in the fastener hole at the aft through-beam (**Figures 3.120-21**)**.** The reason for the difference in the diameters between the treenail found in the F 32 fastener hole and the fastener holes themselves is unclear. Perhaps the original fastener had a pronounced taper, and the through-beam was designed to be held in place primarily by strake PS 14 or other fasteners: the through-beam itself could have been notched in such a way as to lock it in place in the aperture cut for it in strake PS 14, similar to the design of a through-beam used on the tenth-century wreck YK 5 (**Figure 3.122**).

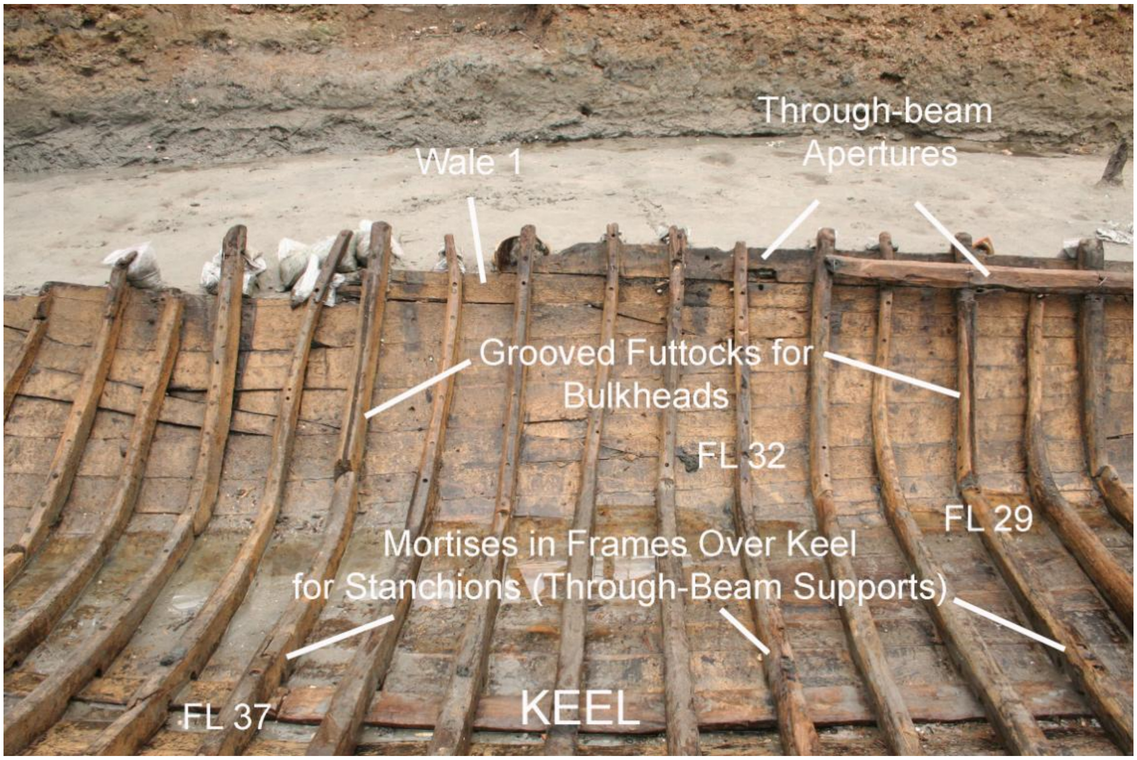

Figure 3.118: Overview of the starboard side between frames 29 and 40. Labels indicate the positions of the keel and wale, stanchion mortises in floor timbers FL 29, 32, and 37 over the keel, openings for through-beams in the uppermost surviving plank at frames 29 and 32 (the opening at frame 29 is not visible from this angle due to the stringer timber at the upper right), and grooved futtocks F 29 and F 37, which were designed for (removable?) bulkheads.

Figure 3.119: Aperture in planking revealing a through-beam location at FL 32, before the dismantling of the hull.

Figure 3.120: Location of a through-beam position on the upper edge of wale PS 13 at FL 32. Note the wear on the upper edge and the thick pitch deposits on the outer face of the wale.

Figure 3.121: Wale PS 13, FL 32 through-beam location at FL 32. The broken treenail at right was removed from the through-beam fastener hole.

Figure 3.122: End of a through-beam in situ, from the hull of the tenth-century ship YK 5.

Pitch ridges on the upper face of the wale indicate the locations where the through-beams rested on the wale and show that they protruded by at least 0.9-1.6 cm beyond the planking. The ridges seem to indicate that the through-beams did not protrude from the hull further than the wale itself. A score mark on the upper face of the wale was also found at the forward edge of the through-beam location between frames FL 31-32 (**Figure 3.123**). The score mark suggests that both through-beams were installed before plank PS 14-2/2-6. At this stage in the construction, some transverse supports inside the hull were probably desirable, and the through-beams would have been much more difficult to install after PS 14 was in place. Also, the apertures into plank PS 14-2/2-6 for the through-beams could be more accurately cut after the through-beams were installed, when the exact locations and cross-sectional shapes of the through-beams were known.

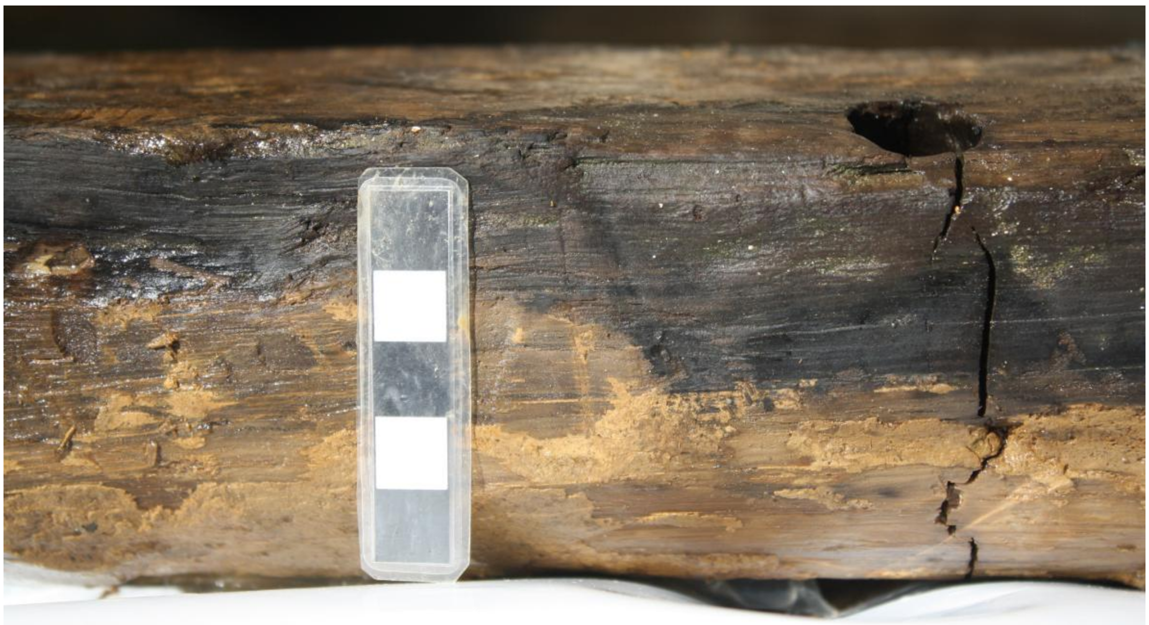

Figure 3.123: A score mark was found at the aft edge of the through-beam at FL 32 on the upper edge of wale PS 13. About half of the score mark had been covered by pitch.

A third possible through-beam location occurs at the broken aft end of the wale between frames 10 and 11. Although poorly preserved, the break occurs at what appears to be a partially preserved drilled hole, which is angled in the same orientation as the fastener holes at the through-beams at frames 29 and 32 (**Figure 3.124**). Through-beams would be necessary for a stern deck in this area, so a third through-beam in this location is plausible.


Figure 3.124: Remains of a possible drilled hole for a through-beam at aft end of wale PS 13, between frames 10 and 11.

Based on the upper planking of other cargo ships from Yenikapı, planking strakes and wales would alternate.[358] YK 1, a late tenth-century merchant vessel with many similarities to YK 14, was built with four wales, separated by narrow strakes of hull planking fastened to the frames and with similar dimensions to wale PS 13.[359] A similar arrangement for YK 14 is likely. The long-arm ends of the floors on the starboard (PS) side amidships are either broken off at the upper end of PS 14 or are preserved up to the

[358] Alternating wales with single strakes occurred on YK 1, 4, 5, 11, and 23, as well as other Roman- and Byzantine-period shipwrecks (see Chapter VII).
[359] This statement refers to the original design of the ship. Additional strakes and a caprail were later added to the hull during an overhaul (see Chapter VII).

level of the now missing strake PS 15, which was likely a second wale. PS 15, or a wale higher in the hull, could have supported a mast partner or additional through-beams.

Strake PS 14

Strake PS 14 consists of three planks: PS 14-l, PS 14-2/1, and PS 14-2/2-6. Both scarf ends preserved on the strake were fastened with coaks; the forward scarf on PS 14-2/2-6 was fastened with a coak to wale PS 13 at its tip, while all three planks in the strake were fastened to each other (but not to the wale) with coaks in a diagonal scarf between frames FL 18 and F 19. The smallest plank, PS 14-2/1, is a repair piece added to the scarf between PS 14-1 and PS 14-2/2-6 when the tip of the scarf broke off during construction. The raised areas at floors FL 12 and 14 are similar to those on the wale, and indicate that the plank was shaped to fit pre-erected frames. Presumably, this 'frame-first' construction technique was used for all of the succeeding strakes as well. Since the upper edge of PS 14 is heavily worn, it is unclear whether notches similar to those seen on the upper edges of the planks below wale PS 13 were present on the higher strake as well.

Two through-beam apertures were cut into PS 14's lower half to accommodate the through-beams fastened to wale PS 13 (**Figures 3.125-26**). These features provide approximate cross-sectional dimensions for the original through-beams. The forward of the two apertures, located just aft of FL 32's location, is 9.1 cm wide and 4.2-4.3 cm deep. The aft aperture was cut just aft of the location of futtock F 29; it is 8.9 cm wide and 4.4-5.0 cm deep. The through-beam apertures were spaced approximately 66 cm apart, edge to edge. A crack in the plank, which runs from the edge of the through-beam aperture forward under the floor FL 32, was repaired with caulking in antiquity (**Figure 3.127**). Based on the edges of the apertures, each was made with two saw cuts into the inboard edge of the plank, approximately 9 cm apart, to the desired depth, after which the wood between the cuts was removed with a chisel.

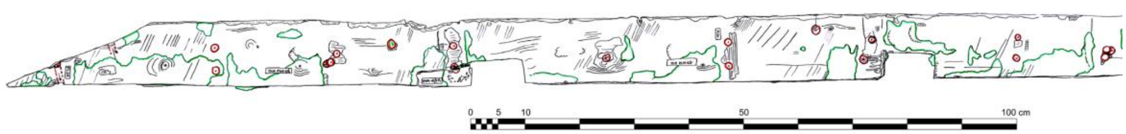

Figure 3.125: Overview of the through-beam apertures on PS 14-2/2-6.

Figure 3.126: Detail of through-beam notch at F 29.

Figure 3.127: Through-beam notch on PS 14 at FL 32, showing caulking repair to old damage around the through-beam aperture.

An unusual feature of strake PS 14 is the use of two to three overlapping treenails at frame locations F 13, 15, 17, FR 19-28, and FR 32-34. Two treenails occur at many of the floor-end locations, but three treenails occur only at six futtock locations at F 13, 19, 21, 23, 27, and 33. Many of these treenails are driven through one another. Some are repairs, having been caulked on the plank in antiquity; for example, at F 19 and F 31. In a number of cases, one treenail at each of the futtocks is for fastening stringer ST-1; these include treenails at F 21, 23, 25, 27, 29, 31—from which ST-1 was removed during the excavation—and possibly also F 33, F 35, and F 37. Since ST-1 is broken on both ends, it is likely that it continued across the length of the hull; some of the treenails in other futtock locations forward and aft of the preserved section of the stringer were likely stringer fasteners as well. The presence of the other treenails could perhaps be explained in two ways. They may have been driven during construction and deliberately overlapped in order to fasten the futtocks and plank more securely, similar to the use of treenail wedges; this measure was perhaps made necessary by the lack of planking edge fasteners in this section of the hull. Or, the additional treenails may have been added in these locations later to replace treenails that had loosened over time.

Repair Components

In addition to pitch and caulking repairs and use of additional fasteners, 12 repair or replacement planks have been identified in the hull (**Table 3.9**). Several are graving pieces, used in rotten areas on the seams that were too large to repair using pitch and caulking alone. This category of repair includes SS 5-2A, PS 3-1A, PS 5-2, PS 5A/1-1A, and PS 11-2/6 (**Figure 3.128**). Repair pieces set into the ends of diagonal scarfs, such as PS 6-2/1 and PS 9-2/5, could also be included in this category. In other areas, larger sections of strakes required removal, such as SS 6-2A, PS 6-2/2-4, PS 4-3, and the adjacent repair planks PS 2-1/1-2 and PS 2-1/3. Most of the repair pieces were installed at the turn of the bilge area of the hull, which suggests that this area was particularly susceptible to rot and wear.

Table 3.9: Dimensions of Replacement Planks

Plank No:	Length (cm):	Width Range (cm):	Thickness Range (cm):
SS 6-2A	143.2	9.0-14.5	2.0-2.5
SS 5-2A	29.4	4.9 (max.)	2.4-3.1
PS 2-1/1-2	143.4	9.4-11.9	1.1-2.8
PS 2-1/3	74.4	9.7-11.6	2.1-2.4
PS 3-1A	46.7	5.0 (max.)	1.8-2.7
PS 4-3	56.8	10.8-12.4	1.7-2.4
PS 5-2	108.4	7.3 (max.)	1.4-2.1
PS 5A/1-1A	100.6	3.4-6.2	1.6-2.1
PS 6-2/1	32.3	8.4 (max.)	1.5-1.9
PS 6-2/2-4	185.8	9.8-15.0	1.4-2.25
PS 9-2/5	31.1	1.-8.1	1.7-2.3
PS 11-2/6	33.1	6.0 (max.)	2.2-2.6

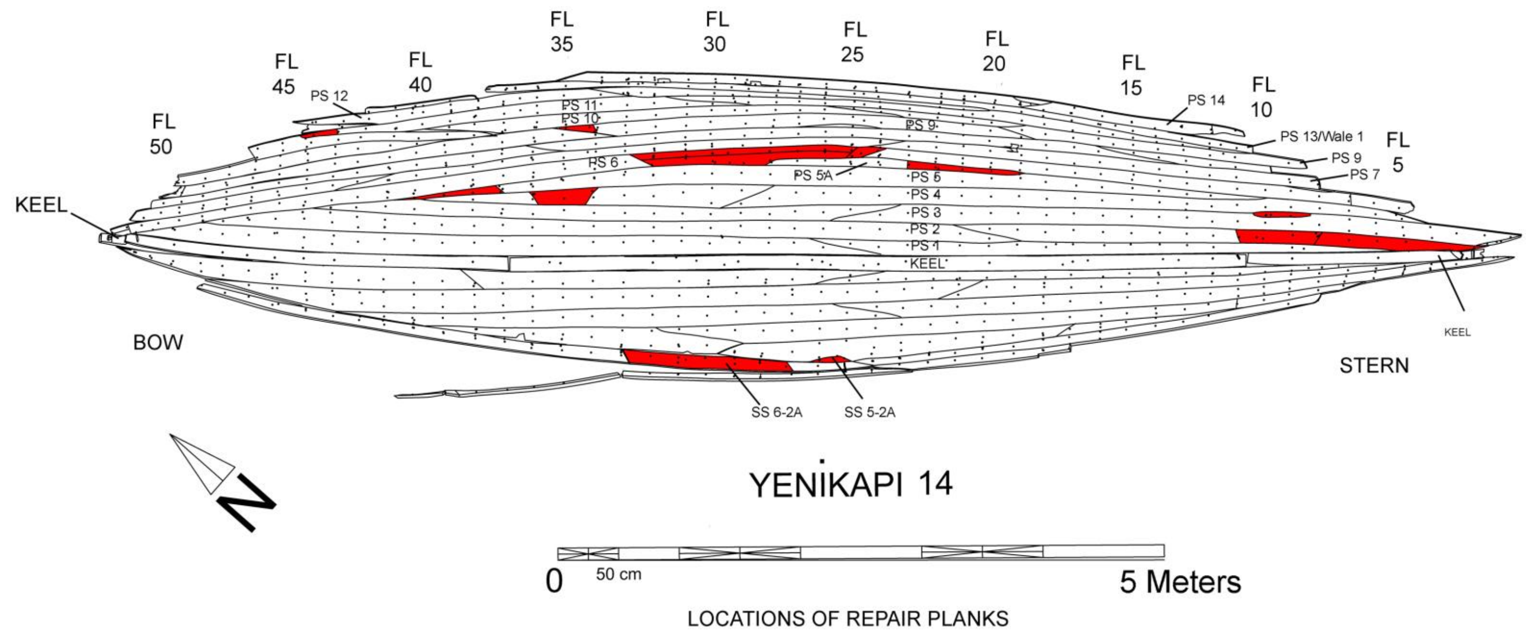

Figure 3.128: Plan of YK 14 showing repair pieces in the hull planking.

Of the 12 identified replacement planks, all show evidence of previous use as hull planking. In all but one case (plank PS 11-2/6), coaks, which had been installed during the plank's previous use in another vessel, were present on the plank edges; one indication that these are repair pieces is the fact that these coaks had been cut in antiquity and did not line up with coaks on the adjacent strakes. Some coak locations on the repair pieces were clearly marked by scoring lines similar to those marking coak locations on the original hull planks. No effort was made to edge fasten the repair planks when they were installed in the hull. Repair pieces were fastened to the frames with iron nails, usually driven through drilled pilot holes, or with treenails. Thick caulking was driven into the seams around the repair planks, usually 0.5-1.0 cm thick, although some deposits were even thicker. Evidence for frame locations on the repair pieces from their previous uses are also apparent, including pressure marks from the edges of frames, areas of rot damage at the previous locations of frames, and unused fasteners or fastener holes. Original fasteners were either cut treenails—several repair planks have treenails cut through on the edge of the plank—or nail holes that had been packed with caulking and pitched over. Evidence for frame locations was covered by a heavy coating of pitch on several of the repair planks as well (**Figure 3.129**).

Figure 3.129: A detail of repair plank PS 6-2/2-4. The large caulked hole at center appears to be plugging a rotten treenail hole from the previous use of the plank. The treenail to the left is from the plank's use on YK 14.

Two repair planks, SS 5-2A and SS 6-2A, were inserted in the port side of the hull at the turn of the bilge. Graving piece SS 5-2A, the smaller of the starboard repair planks, is 29.4 cm in length, with a maximum width of 4.9 cm. The piece is inset into the outboard edge of SS 5-2A between FL 25 and 26 to replace a rotten or damaged area of the hull (**Figure 3.130**). Fasteners from the previous use of the plank include a single coak that was cut off on the inboard and outboard edges, and a partial treenail cut off on the plank's inboard edge. SS 5-2A was fastened to FL 25 and FL 26 with a pair of nails driven through drilled holes 1.4-1.5 cm in diameter; nail head impressions and caulking wrapped around the nail shafts, and packed into the pilot holes, were well preserved on the outer face at both fasteners. SS 6-2A is a larger repair piece, 1.432 m in length and fastened between FL 27-32 (see **Figure 3.80**). Evidence for six frame locations from the previous use of the plank has survived. They include caulked drilled holes from the fastening of the plank to five frame timbers from its previous use on a different ship. Additionally, four coaks—two in each edge, three with score marks indicating their locations on the inner face from the plank's original use on another ship—were found on the inboard and outboard edges of the plank, dating to the original use of the plank.

Figure 3.130: Inset graving piece SS 5-2A in situ.

More extensive repairs were undertaken on the starboard side of the ship. A large section of strake 2 was replaced in the stern area, beginning from the aft end of Keel 1 at FL 3, up to FL 11. The after-most timber, PS 2-1/1-2, is a re-used hood end plank with six fastener holes at its hood end, only three of which were used on YK 14; five frame locations from the plank's previous use are also discernible. Five coaks, including two with well-preserved score marks at their locations in the inner face, are from the original use of the plank, as are two caulked holes and treenails between FL 6-7 and FL 7-8, which appear to be frame fasteners from the previous use of the plank on a different ship.


Figure 3.131: Aft hood end of PS 2-1/1-2.

PS 2-1/3 is a second repair piece added to the hull between FL 8-11, terminating in short diagonal scarfs at each end (**Figure 3.132**). Two coaks, one on the inboard and one on the outboard edge of the plank, a caulked drilled hole under FL 9, treenails for frame fasteners between FL 9-10 and FL 10-11, and a partial treenail cut off on the inboard edge of the plank between FL 10 and 11 are fasteners from the previous use of the plank. PS 2-1/3 was fastened to FL 8 with a nail and a treenail, to FL 9 with a nail in a drilled pilot hole 1.2 cm in diameter, and to FL 10 and FL 11 with single treenails.

PS 3-1A (also shown in **Figure 3.132**) is a small filler or graving piece added to the PS 2-PS 3 seam to repair what was probably a rotten area; two cut coaks (one with a score mark) on its edges indicate that the piece was obtained from a previously used plank. PS 3-1A was fastened to FL 9 with a treenail and FL 10 with a nail. A treenail between FL 9 and FL 10 and a partial treenail cut off on the keel-side edge of the plank between FL 8 and FL 9 are frame fasteners from the previous use of the plank.

Figure 3.132: PS 2-1/3 and PS 3-1A in situ.

PS 4-3, fastened between FL 34 and FL 36, is also a short repair plank with diagonal scarfs at its ends that was recycled from a plank previously used in another ship. Two coaks, one on either edge of the plank, as well as a treenail under the FL 35 frame location, are from the original use of the plank. On YK 14, PS 4-3 was fastened to FL 34 and FL 36 with nails, which, unusually, were not driven through pilot holes. Grass fibers wrapped around the shafts of each nail, as well as nail head impressions, were preserved on the outer face of the plank. PS 4-3 was fastened to FL 35 with a treenail. Caulking deposits around PS 4-3 ranged in thickness from 0.7 cm to 1-2.15 cm.

As with the port side of the ship, the most extensive repairs occur in the area of the turn of the bilge on the starboard side. These include the repair planks PS 5-2, PS 5A/1-1A, PS 6-2/1, and PS 6-2/2-4. PS 5-2 is a 108.4 cm-long, narrow filler piece with a maximum width of 7.3 cm at its aft end. It was cut to shape from a previously used plank and inserted between FL 36 and FL 40; it is somewhat worn and appears to have been slightly compressed in some areas. Damage from wood rot is clearly apparent at the forward end of PS 5, an indication for the reason for PS 5-2’s insertion (**Figure 3.133**). Four coaks from the original use of the plank—three on the outboard edge and one on the inboard edge—were cut in antiquity before the plank’s re-use in YK 14. Two treenails, which were cut off on the inboard edge of the plank between FL 38-39 and FL 39-40, as well as a partial treenail in the aft scarf edge at FL 36 and two treenails in the location of FL 37, are from four frames fastened to the plank during its original use. PS 5-2 was fastened to YK 14’s frames with nails at FL 37, FL 39, and FL 40, and with a treenail at FL 38. Caulking around the plank's edges was poorly preserved, with only a few patches and fibers remaining; perhaps the plank is an older repair to the hull.

Figure 3.133: The dry rot-damaged forward end of PS 5 on the PS 5/PS 5-2 scarf edge. PS 5 was trimmed down in this area to install replacement plank PS 5-2.

PS 5A/1-1A is a similar repair piece inserted between FL 19 and FL 23 (**Figures 3.134-35**). Damage from rot is clearly apparent on the forward scarf of the badly worn adjacent plank, PS 5A/2-4. PS 5A/1-1A is fastened to the frames only with treenails. Evidence for two coaks from the previous use of the plank was found on the plank's edges, as well as a caulked fastener hole and a partial treenail on the plank's inboard edge. Caulking between 0.2-0.7 cm thick was found on the plank's seams and was especially well preserved along its outboard edge. This is in marked contrast to the poorly preserved caulking along the seams of the original section of the strake, PS 5A/2-4.

Figure 3.134: Inner face view of the repair ‘scarf’ between PS 5A/2-4, an original plank which was cut out due to wood rot under the frames (left), and PS 5A/1-1A, a repair plank (right). Note the irregular edge on PS 5A/2-4 due to the damage from rot.

Figure 3.135: View of the inboard edge of the seam between PS 5A/2-4, an original plank damaged by rot (left), and the repair plank PS 5A/101A (right).

Figure 3.136: Forward scarf end of PS 5A/1-1A.

A large section of PS 6 between FL 24 and FL 32 was replaced with two repair planks. The aft repair plank, PS 6-2/1, is a small filler piece replacing a damaged end of a diagonal scarf nailed to the frames FL 24 and FL 25. PS 6-2/2-4, which runs between FL 25 and FL 32, is a somewhat worn, recycled plank piece with evidence for six frame locations from its previous use in the form of fasteners and damage from wood rot, much of which was later pitched over.[360] Drilled holes for coaks and cut coaks were found along the plank's edges; the locations of four coaks had been marked by scoring, which were discovered under the pitch on the plank's inner face. A split along the center of PS 6-2/2-4 (the pith of the original timber) was found to be heavily worn and was repaired with caulking in antiquity (**Figure 3.137**). Although both pieces could have been

[360] A severely rotted area forward of the FL 27 location on the plank, possibly from the plank's previous use, was repaired with a plug of pitch and caulking. The severe dry rot damage which occurred on PS 6-2/2-4 under FL 26, however, was not repaired, indicating that the plank had been a part of YK 14's hull for a considerable time when the ship sank.

installed simultaneously, it is possible that PS 6-2/1's unusual shape is due to its function as a repair addition to the more heavily worn repair plank PS 6-2/2-4. A number of 'blind' fastener holes on the outer faces of frames in the areas of these repair planks suggest that previous attempts to repair this section of the hull may have been made, which are not in evidence on the planks themselves.

Figure 3.137: A caulked split along the outer face of PS 6-2/2-4.

PS 9-2/5 is a filler piece used to replace a rotten area in the forward scarf of PS 9-2/1-4 **(Figure 3.138**). The irregular surface on the forward scarf end of PS 9-2/1-4 is clearly due to damage from wood rot. The aft end of the plank appears to have been held in place by a nail driven into the edge of the scarf seam between PS 9-2/1-4 and PS 9-2/5, and a treenail in the aft end of the piece at F 35. Caulking on the inner face of the filler piece around FL 35 indicate that it was an area of leakage, which required repairing, probably due to a longitudinal crack in the edges of the plank around a treenail hole. A single coak from the original use of the plank was found on the upper edge of PS 9-2/5, as well as evidence of frame fasteners from its previous use, including a pitched-over partial drilled hole in its lower edge and a second cut treenail near the aft end of the filler piece between FL 34-35.

Figure 3.138: PS 9-2/5 in situ, with a caulked repair around the treenail hole at FL 35.

PS 11-2/6 is a 33.1 cm-long, narrow graving or filler piece at the forward end of PS 11-2/1-5 (**Figures 3.139-40**). The irregular surface on the forward end of PS 11-2/5 shows that this piece was also replacing a rotten section of planking in the hull. An extra fastener hole, found concealed by pitch, was located in this piece at FL 43, in addition to a caulked drilled hole forward of the F 44 treenail. The forward end of PS 11-2/1-5 shows clear evidence of damage by rot at a coak hole, which must have precipitated the insertion of the repair plank. No evidence for coaks in the edges of PS 11-2/6 was found, making it unique among the repair planks in YK 14. The wood type (*Fraxinus excelsior*), is also unusual for a hull plank from YK 14. The caulking along the edges of PS 11-2/6, which contain long fibers pressed along the edges of the plank seam's outboard side along with thick pitch deposits, are likely examples of driven caulking deposits.

Figure 3.139: PS 11-2/6 in situ, a repair piece added to a scarf tip.

Figure 3.140: The inner face of PS 11-2/6 after cleaning.

The construction methods in evidence from the planking repairs are remarkably consistent with the original construction methods used in YK 14. The vessel or vessels whose planking was salvaged to repair YK 14 were built using nearly identical methods and materials to those used in the construction of YK 14. The techniques used to make the repairs themselves were simple and consistent. Planks were roughly cut down with adzes and nailed or treenailed to frames—the use of both nails and treenails to fasten the same repair planks could perhaps be related to a shortage of available nails. Nails shafts were often wrapped in caulking fibers and pitch and driven into pilot holes with similar diameters to those drilled for treenails during the initial construction of the ship. The evidence for construction using coaks on nearly all of the repair planks suggests that mortise-and-tenon construction had been abandoned at Yenikapı long before 900 C.E.; on the INA-excavated shipwrecks from Yenikapı dating to after the seventh century, planks with mortise-and-tenon joints do not appear even among repair pieces, which were presumably salvaged from local derelicts.

Based on the condition of the planks, the preservation of caulking along the plank seams of repair pieces, and other factors, it appears that some repairs are older than others. The repair planks in strakes PS 5, 6, and 9, and SS 6 are perhaps older than those in SS 5 and PS 5A. However, there is no way to verify whether some pieces were added to the hull before others; several repair planks could have been added during one major overhaul, but it seems far more likely that repair planks were added in several separate episodes. Variation in the age and condition of salvaged planks should also be expected, which further complicates any attempts to determine the sequence of repairs to the hull.

Several planks, which are clearly distinguishable from later repair planks by the fact that they were fastened in the hull with coaks, appear to be ‘repairs’ made during construction when a plank to be installed in the hull was damaged. Several examples have already been mentioned, including the Keel 1/ Keel 2 scarf, PS 14-2/1, a repair to the PS 14-1/PS 14-2 scarf, and possibly the garboard plank SS 1-1/1. One additional piece, PS 9A, must also be a repair made during construction. PS 9A is a small filler piece, 62.8 cm long, and with a maximum width of 3.4 cm. It was fastened to an indented area along the inboard edge of PS 9-2/1-4 with three coaks between the FL 24 and FL 27 frame locations, and to floor FL 25 with a single treenail. The wood grain on PS 9A runs in a different direction than the wood grain on PS 9-2/1-4, an indication that it was cut from a different plank; it seems that PS 9A must have been added to repair a split in PS 9-2/1-4 that occurred during construction. In addition to repair pieces in the form of planks, evidence for possible repair frames at FL 44 and F 44 are described in detail in the next section.

5) Timber Catalog: Frame Timbers

Frames preserved in YK 14's hull include 45 floor timbers, twelve of which were recovered complete and six others nearly complete, and seventeen futtocks, of which eleven were recovered complete or nearly complete.[361] Based on fastener holes in the keel timbers and hull planking, the ship had an estimated 50 to 52 original floors. Only 20 or 21 of these floors were fastened to the keel with iron nails. The pattern of nailed floor timbers varies, but in the main body of the ship every second or third frame is nailed to the keel; towards the bow several consecutive floors are nailed to the keel timbers. Thirteen UM timbers recovered from the wreck site are frame fragments, most of which have clear similarities to the in-situ frames found in the hull and are almost certainly from YK 14.

Preservation

Most of the ship's frames are in good to excellent condition, although many were lacking in structural strength. The upper ends of exposed floors and futtocks were not as

[361] Complete floor timbers include FL 14, 16, 18, 20, 22, 26, 30, 32, 36, and 44. FL 7 and 34 are probably complete, but have badly worn or damaged ends. Nearly complete floors with slight damage or breaks near port end include FL 12, 24, 28, 38, 40, and 42. Complete futtocks include F 21, 23, 25, 27, 29, 31, 33, 35, 37, 39, while F 19 is a nearly complete futtock.

well preserved: the ‘long arms’ of the floors extending above the turn of the bilge are particularly delicate. Teredo worm damage was present in some of the upper ends of futtock timbers along the starboard side. Dry rot damage to the outer faces of the timbers affected most of the frames, but had seriously damaged only a few, particularly in the extremities of the hull (e.g., FL 4-6, 8-9, 38, and FL 40). Preservation of tool marks and other surface detail on most of the hull timbers was excellent, particularly in areas covered by pitch. The pitch layer on the frame timbers was generally thinner than on the hull planks. Although all exposed faces of the timbers seem to have been originally covered in pitch, pitch preservation on the inner faces of the timbers was generally very poor; the best pitch preservation tended to occur on the flat, sawn faces of the frames.

Wood Species Used for Frames

The majority of frames were made from Turkey oak, the most common wood type used in the construction of YK 14; in all, 37 floor timbers and eight futtock timbers were made from this species. Smaller numbers of frames were made from another oak species, Sessile oak (*Quercus petraea*), as well as from European ash (*Fraxinus excelsior*), and Sycamore maple (*Acer pseudoplatanus*) (**Table 3.10**).

Table 3.10: Wood Species of Frames

Wood Species:	Total No. of Floors:	Total No. of Futtocks	Timber Numbers:
Quercus cerris (Turkey oak)	37	8	Floors: FL 6-32, 37-40, 43-48; Futtocks: F 21, 27, 29, 31, 35, 37, 39, 41
Quercus petraea (Sessile oak)	6	2	Floors: FL 33-36, 41-42; Futtocks: F 33, F 45
Fraxinus excelsior (European ash)	0	7	Futtocks: F 11, 13, 15, 17, 19, 23, 25
Acer pseudoplatanus (Sycamore maple)	2	0	Floors: FL 4, 5
TOTAL	45	17	

Fabrication of the Frame Timbers

Tool marks indicate that nearly all of the frame timbers were shaped using the same techniques. The cross sections of the frame timbers consisted of approximately one quarter to one half of the original timber. The number of tree rings visible in cross sections or ends of each frame varies from under ten rings to 55-60 growth rings, but most have a cross section with approximately 15-25 rings.

The floors used in the main section of YK 14 are fairly straight up to the turn of the bilge, with only a slight increase in the molded dimension in the area of the garboard strake before the limber holes (**Figure 3.141**). Floors were shaped from naturally curved compass timber, usually cut from one-half of a relatively young log with a protruding tree limb. Each timber was sawn longitudinally on one side.

Figure 3.141: Floors 26, 28, 30, 32, and 34 in situ, during the dismantling of the ship, May 2007.

While the pith was visible on the cross sections of some floor timbers, others in the central section of the ship may have been sawn into pairs of identically-shaped, 'L'-shaped floor timbers, each with a 'long arm' extending above the turn of the bilge to the waterline, and a 'short arm' opposite, which ends at the turn of the bilge (**Figures 3.143-57**).[362] This method of cutting timbers could have allowed the builders to make pairs of roughly symmetrical floors that could be oriented in opposite directions in the central section of the hull. Score marks occur at the turn of the bilge area on the forward, adzed faces of two floor timbers; these may have been made by the shipwright to mark the curved turn of the bilge area on the frames.[363] Futtocks were shaped using similar methods; all had a single 'flat' sawn face, while the other three faces were shaped or

[362] This is difficult to confirm, since cross sections of the timbers are rarely visible in the same location.
[363] These include FL 22 (5 cuts at the beginning of the turn of the bilge on the adzed forward face) and FL 28 (3 cut marks on the sawn aft face in middle of turn of the bilge area).

finished with adzes. The U- and V-shaped floor timbers towards the ends of the ship were also cut from more irregular compass timbers, and consequently showed more variation in shape and shaping methods.

The ‘long arms’ of the floor timbers run past the turn of the bilge to the waterline level, ending at strake PS 14 or PS 15. Complete floor timbers survived between FL 14 and FL 44, and therefore cover most of the length of the hull. Odd-numbered floor timbers, whose ‘long arms’ were oriented towards the port side, were broken at the turn of the bilge area (strakes SS 6-7 for most floors), but would have had the same design as the complete floors preserved on the starboard side. Although FL 25 and FL 27 were broken at the turn of the bilge like the other odd-numbered floors on YK 14, the pieces of the upper sections of the ‘long arms’ of these floors were recovered on the wreck site.

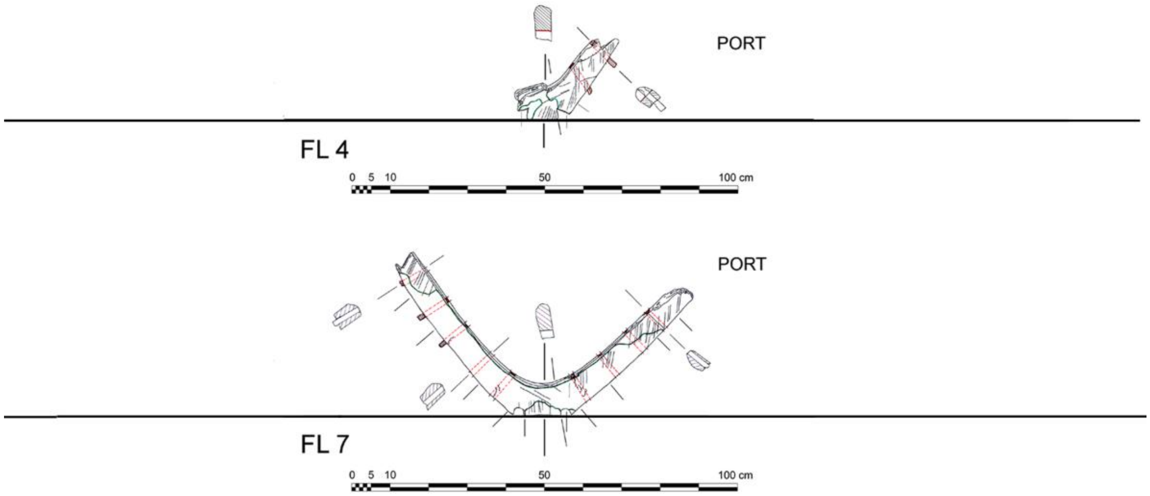

Figure 3.142: FL 4 (above) and FL 7 (below), forward faces and cross sections.

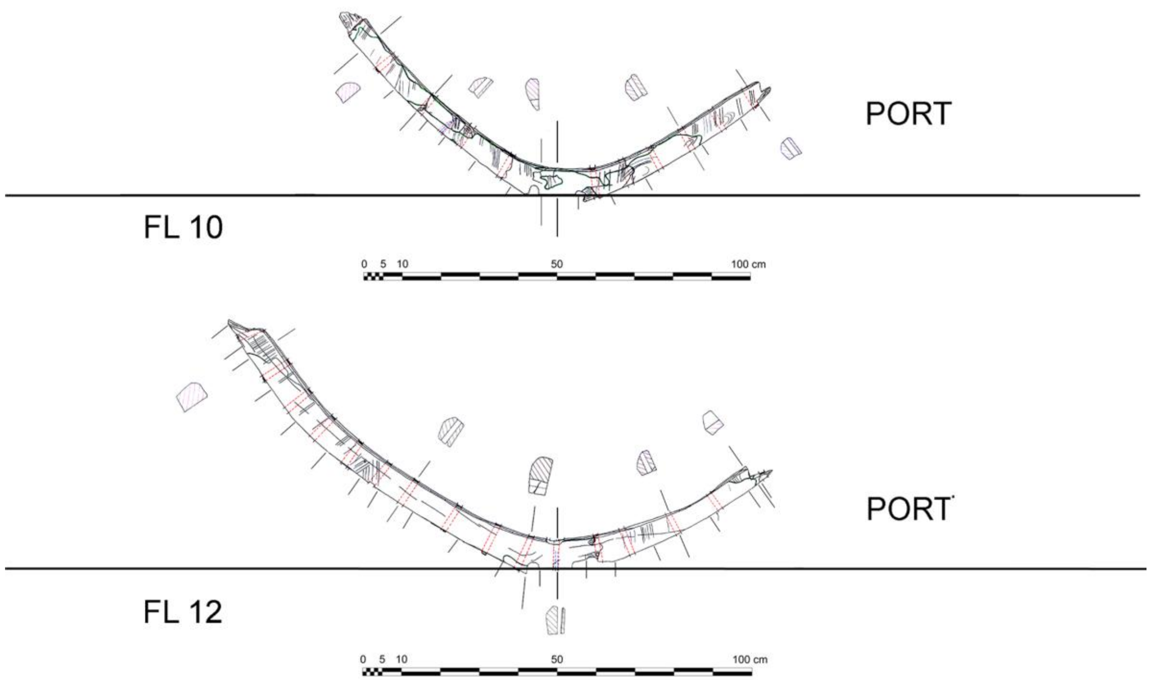

Figure 3.143: FL 10 (above), and FL 12 (below), forward face and cross sections.

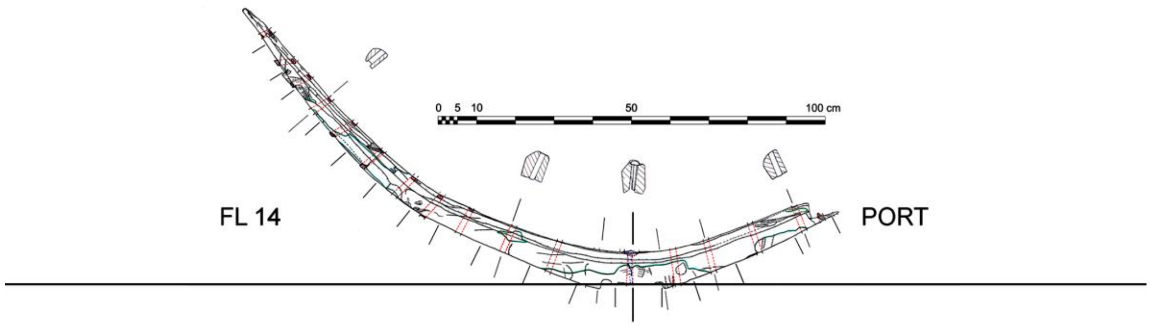

Figure 3.144: FL 14, forward face and cross sections.

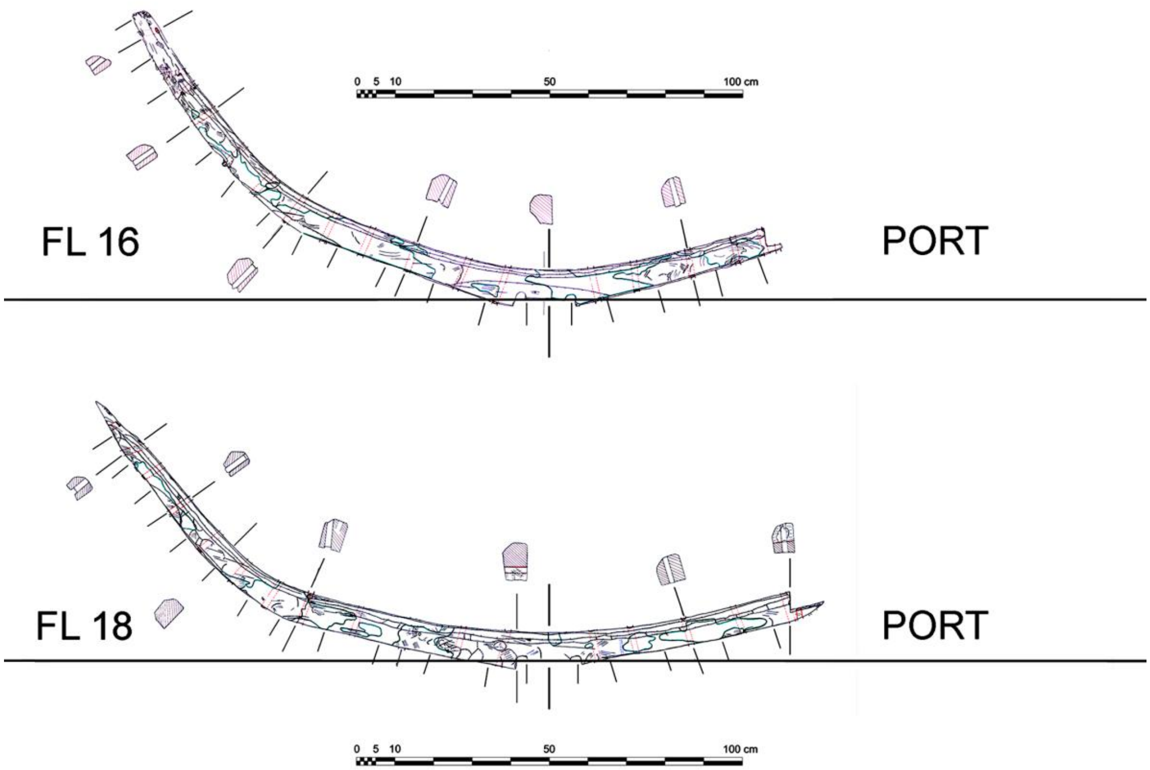

Figure 3.145: FL 16 (above) and FL 18 (below), forward faces and cross sections.

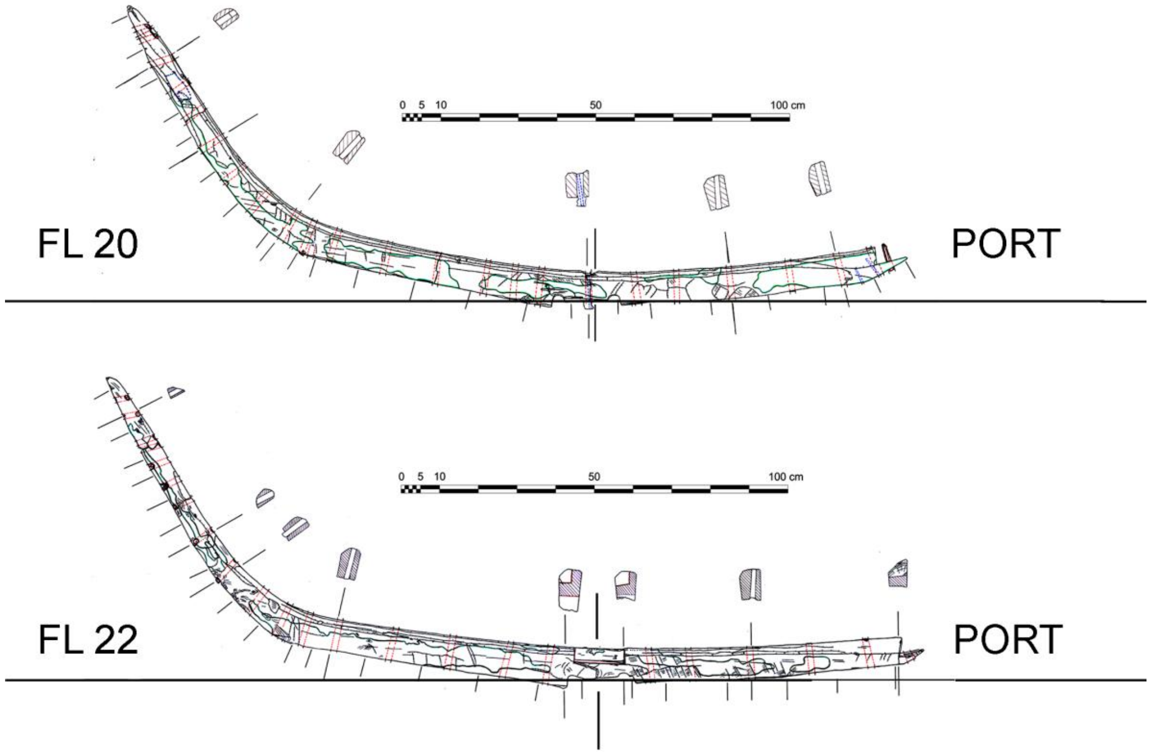

Figure 3.146: FL 20 (above), and FL 22 (below), forward faces and cross sections.

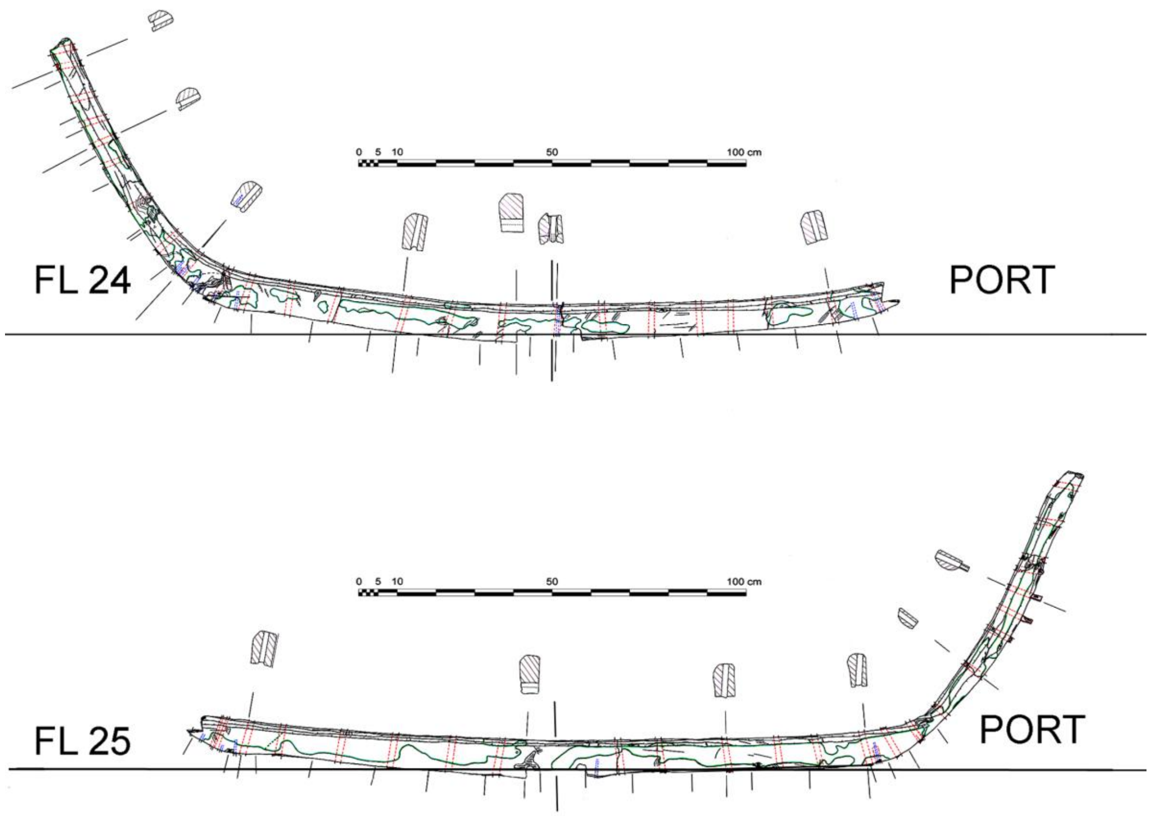

Figure 3.147: FL 24 (above) and FL 25 (below), forward faces and cross sections.

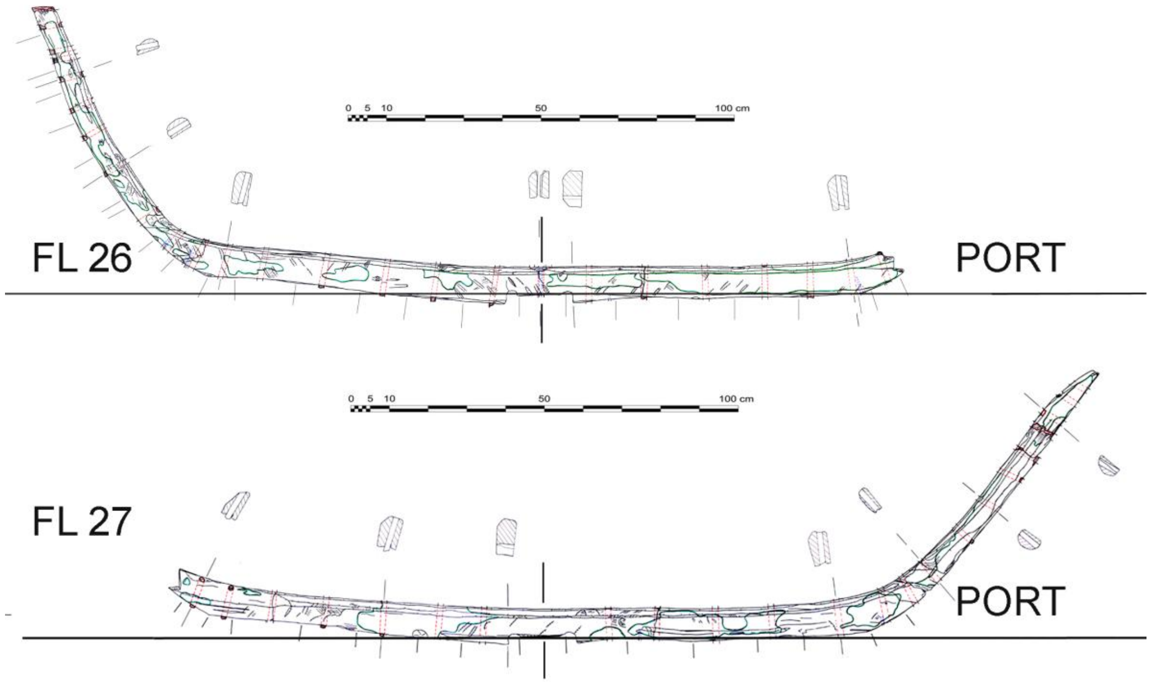

Figure 3.148: FL 26 (above, and FL 27 (below), forward faces and cross sections.

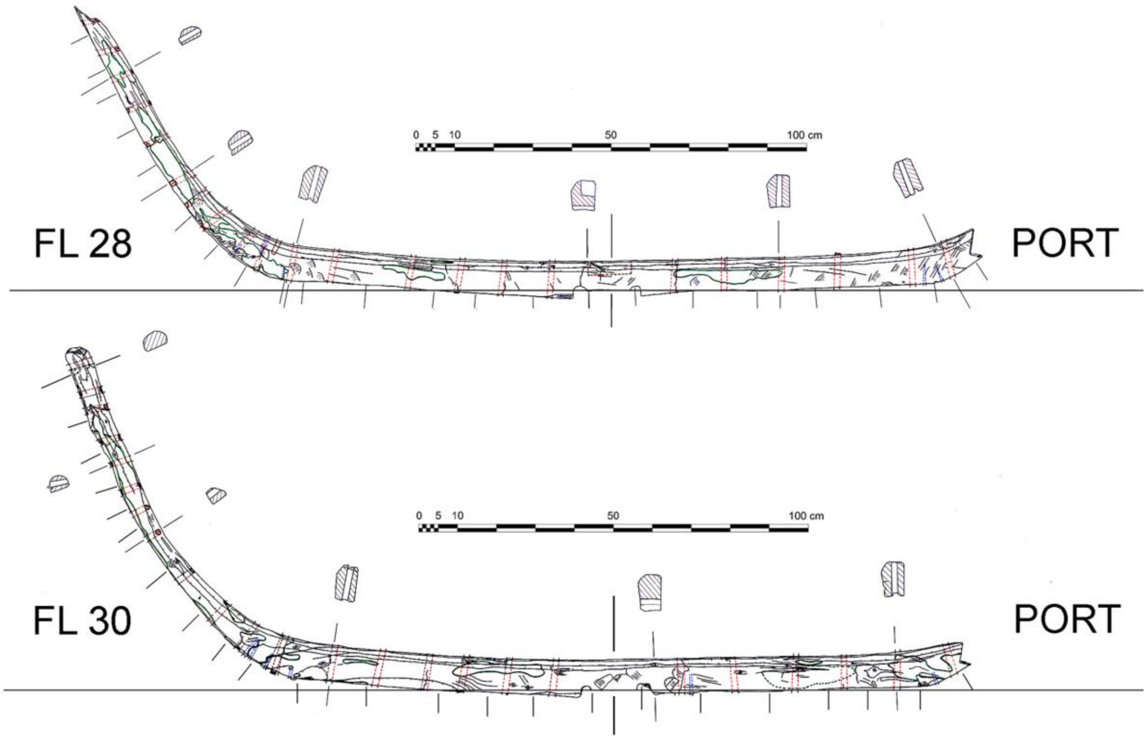

Figure 3.149: FL 28 (above), and FL 30 (below), forward face and cross sections.

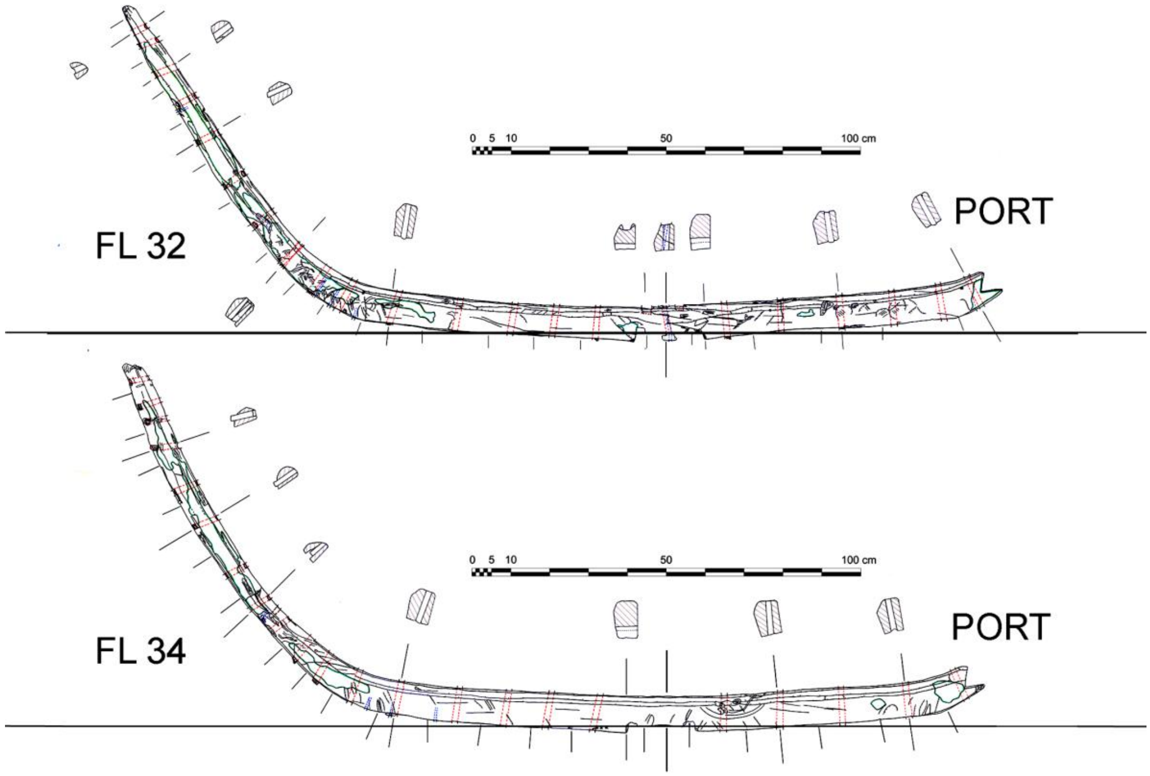

Figure 3.150: FL 32 (above) and FL 34 (below), forward faces and cross sections.

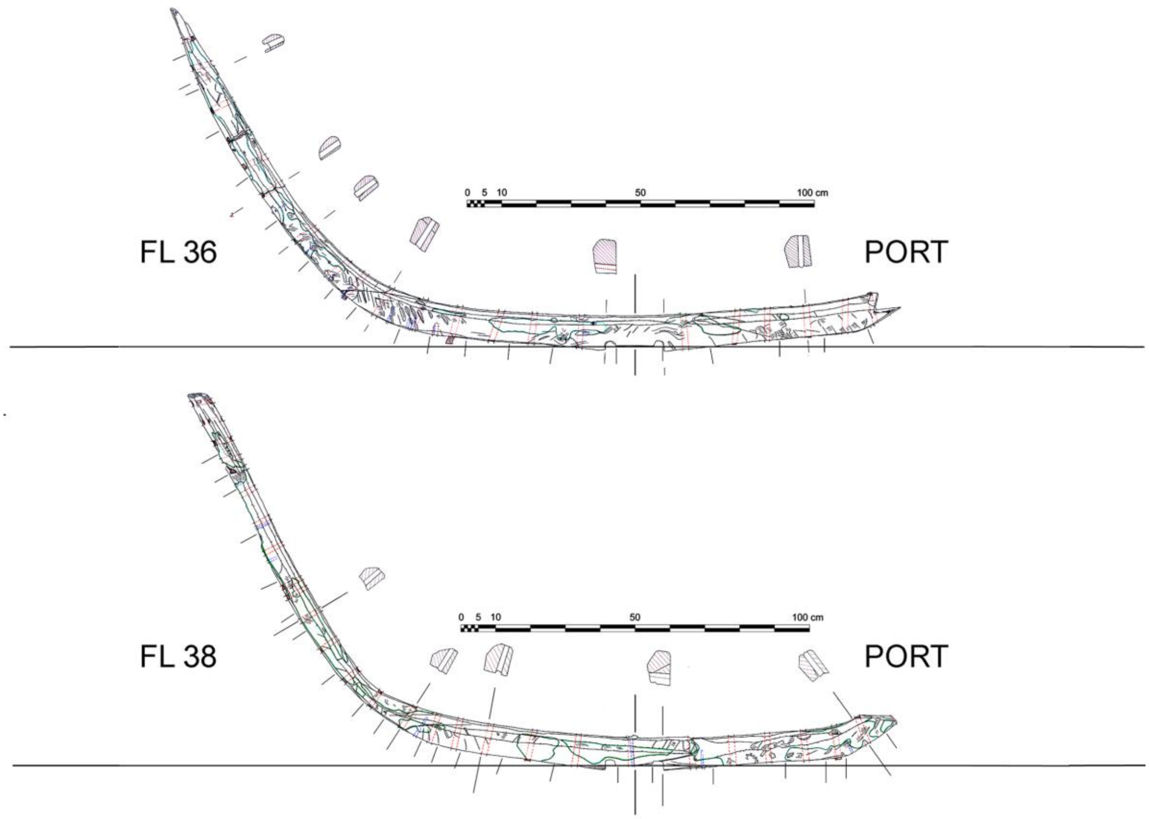

Figure 3.151: FL 36 (above) and FL 38 (below), forward faces and cross sections.

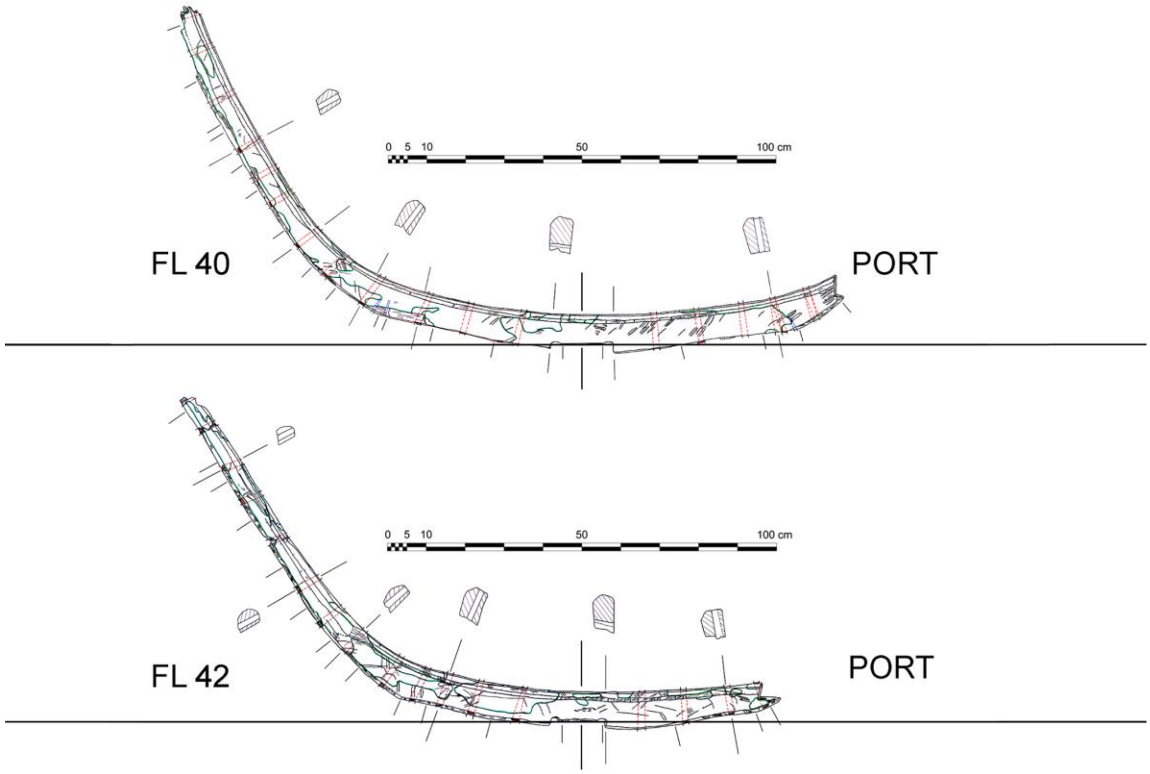

Figure 3.152: FL 40 (above) and FL 42 (below), forward faces and cross sections.

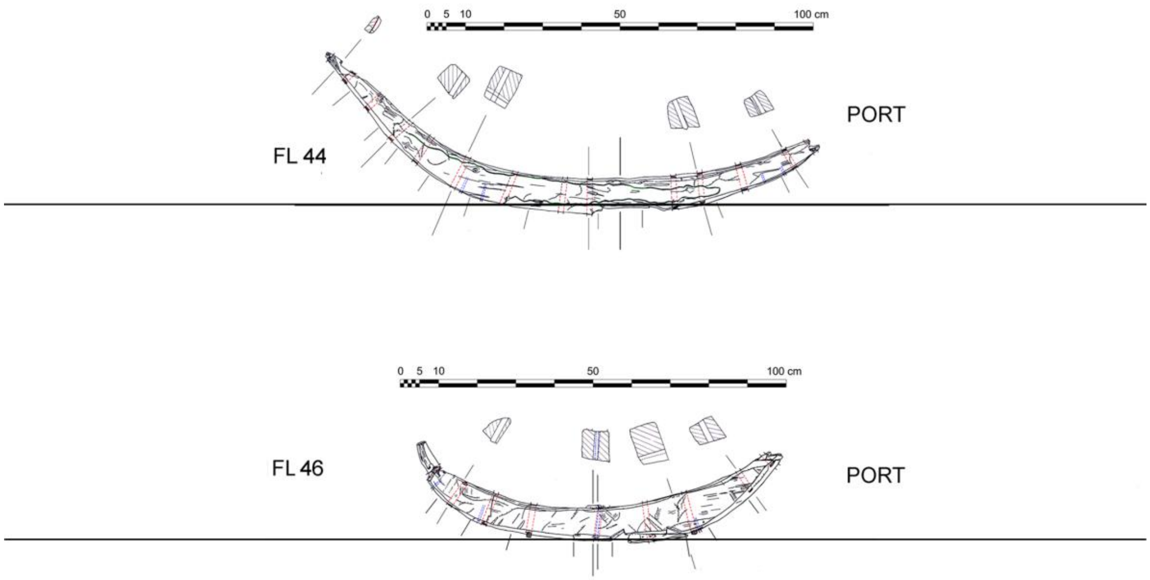

Figure 3.153: FL 44 (above) and FL 46 (below), forward faces and cross sections.

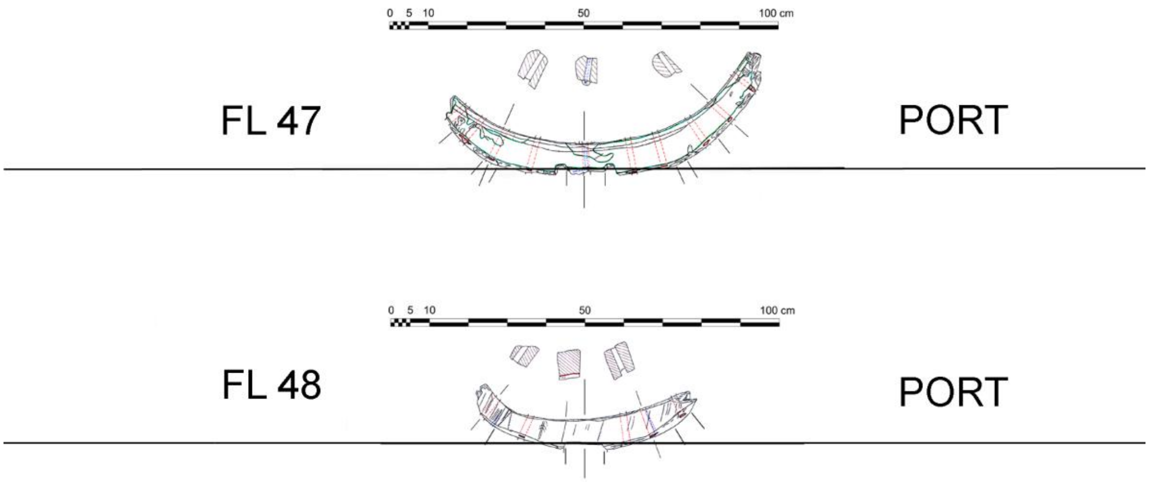

Figure 3.154: FL 47 (above) and FL 48 (below), forward faces and cross sections.

All of the floors in the main body of the ship—from FL 13 to 42 and FL 46 and 47—have their flat, sawn face oriented towards the stern. Many of the frames at either end of the ship, including FL 4-12 and FL 48, have their flat faces oriented in the opposite direction of those in the main body of the ship.[364] Throughout the hull, the sawn faces of futtocks are oriented in the same way as their accompanying floor timbers. The floors were sawn from two different directions due to their shape, with the saw marks meeting above the turn of the bilge on the 'long arm' side, although on shorter floor timbers the saw marks sometimes cross each other in the keel area, particularly on frames near the

[364] Several of the frames at the forward end of the hull are exceptions to this rule. FL 44 is adzed on all faces, while FL 45 was sawn on both forward and aft faces. Similar orientations of the sawn faces of frame timbers were found on YK 5.

extremities of the ship (e.g., FL 40) (**Figure 3.155**). Saw marks were usually somewhat regular except at these points where the saw marks crossed or at the locations of knots. Ten of the floor timbers (FL 6, 17, 19, 20, 31, 32, 34, 35, 37, and 41) and four of the futtocks (F 17, 27, 29, and 35) exhibit adze dubbing on their sawn faces, probably from removing of rough or splintered sections from the face. On both the floors and the futtocks, the dubbing tends to be found near the floor/futtock scarf ends. In the cases of FL 20 and 41, saw marks indicate that the timber was being sawn longitudinally from two different directions, but did not cross as on the other frames; the section between the saw marks in each direction was split away rather than finished with an adze. On F 29, a deep depression was cut rather roughly with an adze to allow the futtock to be placed next to an adjacent through-beam, which must have already been in place when the futtock was being installed (**Figure 3.156**).

Figure 3.155: The flat, sawn faces of the floor timbers were cut from two different directions; the saw marks usually meet either before the turn of the bilge on the 'long arm' or in the keel area, shown here on FL 40.

Figure 3.156: Adzed depression on F 29 cut to fit the futtock around an adjacent through-beam.

The other three faces of the frames in nearly all cases were shaped with adzes (**Figure 3.157**). The inner face edges of the floor and futtock timbers on most frames are chamfered, with a single small chamfer on the edge between the sawn face and the inner face; the chamfers range in width and depth from 0.1 to 1.6 cm, but are usually about 0.5 cm wide and 0.5 cm deep. The opposite corner is usually shaped into a larger, more rounded chamfered surface, usually consisting of three chamfers, whose widths and heights range from 0.8 to 5.3 cm (**Figure 3.158**).[365] These chamfers often exhibit large sections of rounded, un-worked areas of the timber where only the bark was removed. Individual tool marks, typically 2-3 cm long and sometimes exhibiting the striations typical of adze marks elsewhere in the hull, are clearly visible on all of these chamfers. These tool marks indicate that they were cut with an adze rather than a plane or drawknife; both tools would leave a smooth, continuous chamfer rather than the interrupted ones seen on the frames. Also, striations from nicks or irregularities in the tool's blades are visible on many of these tool marks, showing that they were made by blows struck at an angle, rather than parallel to, the lengths of the timbers.

[365] These measurements do not include FL 43, 44, 45, and 48, which had single, adzed chamfers on both inner face edges, 0.2-1.7 cm wide and 0.2-3.3 cm deep.

Figure 3.157: Forward face detail of FL 40 showing well preserved adze marks.

Figure 3.158: Adze marks on the inner face/forward face chamfer on FL 40.

Many of the floor timbers are notable for the relatively small-diameter logs used in their fabrication; YK 14 has light scantling compared to other archaeological examples of

Byzantine ships (see Chapter VII). The dimensions of the floors often vary significantly on the same timber. The molded dimensions on the floors range from 2.6 cm to 11.5 cm (not including tapered frame ends), with an average maximum dimension of 9.5 cm at the keel and garboard areas of the timbers; 4-10 cm is a typical range for molded dimensions on a complete floor timber (**Table 3.11**).[366] Sided dimensions range from 1.0-7.7 cm with an average maximum dimension of 5.8 cm in the keel/garboard area; 4-6 cm is a typical range for sided dimensions on the floors. Average minimum molded and sided dimensions on 24 complete or nearly complete floor timbers are 4.4 cm (molded) and 3.7 cm (sided). The molded dimensions of futtocks range from 3.1 to 8.6 cm, with an average maximum molded dimension of 7.3 cm,[367] while sided dimensions range from 3.2 to 6.6 cm, with an average maximum dimension of 5.4 cm. Molded dimensions of the floors are usually largest in the area of the garboard strakes just outboard of the limber holes. Sided dimensions on the floors before the turn of the bilge were generally very consistent, and decrease slightly on the 'long arms' beyond the turn of the bilge. Most floors have a significant decrease in cross-sectional dimensions above the turn of the bilge. The shape of the sections also tended to change from rectangular or trapezoidal to a more semicircular shape, due to the relatively small diameter of the limbs from which the floor timbers were cut. Many of these floor timbers also have significant

[366] The average maximum dimensions were measured from the outboard side of the limber holes or any nearby area with larger dimensions in the keel/garboard area, which is the case on some of the floor timbers towards either end of the hull. The average maximum molded and sided dimensions were calculated using the larger molded and sided dimensions from either the port or starboard limber hole on each floor timber. The minimum dimensions on the floor timbers were generally past the turn of the bilge, often at the ends of the 'long arms'.

[367] This does not include the grooved futtocks F 29 and F 37, which have larger maximum molded dimensions (10.6 cm on F 29 and 11.2 cm on F 37).

curvatures or undulations in the frame beyond the turn of the bilge, and exhibit only minimally worked surfaces; often only the bark was removed from the surfaces of the floor in this area, but little else (**Figure 3.159-60**).

Figure 3.159: Floors with curved and irregular ‘long arms’ preserved on the starboard side of the ship.

Figure 3.160: Detail of the minimal working of the 'long arm' of FL 30 above the turn of bilge.

The upper ends of the 'long arms' are especially light: on many floors the treenails driven through the upper part of the 'long arm' timber run through half of the diameter of the timber (**Figure 3.161**). This probably accounts for why stringer ST-1 was fastened only to futtocks; at the level of the waterline, the floor timbers are too slender to be fastened to another timber.

Figure 3.161: A treenail at a break in the ‘long arm’ of FL 22 above the turn of the bilge. Note the small cross section of the floor timber at this location.

Table 3.11: Frame Dimensions and Features

Frame No:	Ends (complete/ broken):	Length (m):	Sided Dimensions (range) (cm):	Molded Dimensions (range) (cm):	Notes:
FLOORS					
FL 4	Port end original; starboard end broken	0.318	4.25-4.55	5.80-9.55	
FL 5	Port end broken; starboard end original	0.373	4.55-4.80	6.85-9.00	
FL 6	Both ends broken	0.592	3.95-4.75	5.05-8.90	
FL 7	Port end worn, probably original; starboard end broken	0.768	3.25-4.50	5.80-9.35	
FL 8	Both ends broken	0.910	4.20-5.40	6.10-9.65	
FL 9	Port end broken; starboard end original	1.03	4.20-6.65	5.75-9.45	

Table 3.11, Continued

Frame No:	Ends (complete/ broken):	Length (m):	Sided Dimensions (range) (cm):	Molded Dimensions (range) (cm):	Notes:
FL 10	Port end original; starboard end broken	1.115	0.95-4.50	4.75-8.50	
FL 11	Port end broken; starboard end original	0.538	3.90-4.45	4.25-6.90	
FL 12	Port end original; starboard end broken	1.437	4.20-5.35	4.90-9.75	
FL 13	Port end broken; starboard end original	0.956	4.95-5.65	5.30-8.80	
FL 14	Both ends original	1.625	3.5-6.15	1.2-9.6	
FL 15	Port end broken; starboard end original	1.283	4.35-6.1	5.1-9.65	
FL 16	Both ends original	1.799	4.25-6.25	4.75-10.0	
FL 17	Port end broken; starboard end original	1.404	4.8-6.15	6.5-9.7	
FL 18	Both ends original	1.952	5.0-6.5	3.05-9.7	
FL 19	Port end broken; starboard end original	1.77	4.75-5.8	6.3-10.15	
FL 20	Both ends original	2.126	3.9-6.0	3.05-9.65	
FL 21	Port end broken; starboard end original	1.803	4.9-5.85	5.3-9.05	
FL 22	Both ends original	2.22	2.6-5.9	2.75-10.65	A mortise for the aft end of the mast step was cut in the inner/forward face edge of FL 22, over the keel area
FL 23	Port end broken; starboard end original	1.89	4.9-5.9	6.6-9.9	

Table 3.11, Continued

Frame No:	Ends (complete/ broken):	Length (m):	Sided Dimensions (range) (cm):	Molded Dimensions (range) (cm):	Notes:
FL 24	Port end original; starboard end broken	2.307	3.95-6.05	5.9-9.65	
FL 25	Both ends original	2.40	3.45-5.9	4.3-9.6	
FL 26	Port end original; starboard end broken	2.36	2.55-5.4	5.6-9.45	
FL 27	Both ends original	1.96	4.3-5.55	6.6-9.0	
FL 28	Both ends original	2.41	3.3-6.25	4.2-9.6	A mortise for forward end of mast step cut in the inner/aft face edge of FL 28, over the keel
FL 29	Port end broken; starboard end original	1.967	3.1-6.0	6.7-9.55	A pair of mortises for a stanchion in the inner face of the floor, over the keel
FL 30	Both ends original	2.428	3.8 -6.25	4.85-9.45	
FL 31	Port end broken; starboard end original	1.935	4.75-5.9	6.25-8.9	
FL 32	Both ends original	2.38	4.15-6.2	4.0-8.95	A pair of mortises for a stanchion were cut in the inner face of the floor in the keel area
FL 33	Port end broken; starboard end original	1.850	5.45-6.6	7.3-10.35	
FL 34	Port end original; starboard end is a damaged original end (?)	2.378	3.25-6.35	5.75-9.55	
FL 35	Port end broken; starboard end original	1.710	0.0505-0.066 m	7.1-10.1	
FL 36	Both ends original	2.278	3.1-7.65	4.0-10.2	

Table 3.11, Continued

Frame No:	Ends (complete/ broken):	Length (m):	Sided Dimensions (range) (cm):	Molded Dimensions (range) (cm):	Notes:
FL 37	Port end broken; starboard end original	1.692	5.15-7.15	4.45-10.35	A pair of mortises for a stanchion in the inner face over the keel area
FL 38	Port end broken; starboard end original	2.241	4.15-7.0		
FL 39	Port end broken; starboard end original	1.480	4.9-6.3	6.5-9.55	
FL 40	Port end original; starboard end broken	1.962	4.5-5.8	5.45-9.75	
FL 41	Port end broken; starboard end original	1.196	4.8-6.1	7.15-9.9	
FL 42	Port end original; starboard end broken	1.730	3.4-5.85	4.3-8.85	
FL 43	Port end broken; starboard end original	1.048	4.4-6.75	6.75-11.1	
FL 44	Both ends original	1.315	5.0-7.65	1.45-9.6	Possible repair floor?
FL 45	Port end is broken; starboard end is original	0.969	5.0-6.1	2.75-11.45	
FL 46	Port end broken; starboard end original	0.950	4.3-7.7	3.1-10.6	
FL 47	Port end is broken; starboard end is a damaged original end	0.829	3.25-5.55	5.8-9.2	
FL 48	Port end original; starboard end broken	0.568	5.4-6.6	3.9-8.35	

Table 3.11, Continued

Frame No:	Ends (complete/ broken):	Length (m):	Sided Dimensions (range) (cm):	Molded Dimensions (range) (cm):	Notes:
FUTTOCKS					
F 11	Keel/port end original; port/upper starboard end broken	0.557	3.75-4.15	4.9-6.25	
F 13	Keel/port end original; starboard/ upper end is broken	0.826	4.15-4.9	3.15-6.4	
F 15	Keel/port end original; starboard/ upper end broken or badly damaged	0.680	3.9-4.75	5.0-6.6	
F 17	Keel/port end original; starboard/ upper end broken	0.768	4.2-5.1	5.0-6.65	
F 19	Keel/port end original; starboard/ upper end broken	0.729	3.2-5.65	4.9-7.1	
F 21	Both ends original	0.807	5.0-5.45	6.0-6.95	
F 23	Both ends original	0.750	3.95-5.15	5.1-7.0	
F 25	Both ends original	0.811	4.6-5.25	5.8-7.05	
F 27	Both ends original	0.830	4.65-6.55	5.65-8.55	
F 29	Both ends original	0.865	5.0-5.75	8.05-10.45	Bulkhead futtock: groove cut into inner face
F 31	Both ends original	0.972	4.9-5.65	7.3-7.9	
F 33	Keel/port end original; starboard/ upper end broken	0.932	4.55-5.15	6.55-8.1	
F 35	Both ends original	1.045	4.5-5.05	6.95-7.70	

Table 3.11, Continued

Frame No:	Ends (complete/ broken):	Length (m):	Sided Dimensions (range) (cm):	Molded Dimensions (range) (cm):	Notes:
F 37	Both ends original	0.926	4.9-6.25	7.55-11.2	Bulkhead futtock: groove cut into inner face
F 39	Keel/port end original; starboard/ upper end broken	1.078	5.45-6.1	6.95-8.0	
F 41	Keel/port end original; starboard/ upper end broken	1.071	5.05-6.10	6.6-7.2	
F 45	Keel/port end original; starboard/ upper end broken	0.445	4.55-5.0	6.45-6.80	

The Midship Area of the Hull

The widest point in the hull is between FL 27 and FL 30.The widest complete or nearly-complete floor timbers amidships are FL 25 (2.40 m), FL 26 (2.36 m), FL 27 (2.47 m) and FL 28 (2.41 m); FL 29 was broken at the turn of the bilge, and FL 30 is slightly larger than the frames further aft (2.43 m). FL 32 is 2.38 m in length, slightly narrower than the FL 30. The lengths of these floors were measured from one end of each floor timber to the other; however, FL 26's starboard end is lost and both FL 25 and FL 27 were broken during the wrecking of the ship in several places above the turn of the bilge, so these lengths should be treated with caution. Another factor affecting floor length is the floor/futtock scarfs, which were cut in different locations in relation to the turn of the bilge on different floors. In spite of these sources of uncertainty, the total lengths of the floors in this area do seem to indicate that the largest pair of floors was installed between FL 26 or 27 and FL 30.

Another potentially useful measurement is the ‘flat’ portion of the floor timbers, or the length of the floor to the turn of the bilge on either side of the hull; this dimension was important for determining hull shape in various early methods of skeleton-first construction.[368] Since the beginning of the turn of the bilge is not always apparent on these floors, these measurements are somewhat subjective. Taking this variation into account, the same floors still have the largest dimensions: FL 25 (1.70 m), FL 26 (1.69 m), FL 27 (1.70 m), FL 28 (1.72 m). Floors further forward are slightly narrower, including FL 29 (1.66 m), FL 30 (1.63 m), and FL 31 (1.63 m). The ‘rising’ of floors FL 25-28 is essentially the same, but the ‘long arms’ of FL 27 and FL 28 flare out slightly more than those of FL 25 and FL 26. For these reasons, FL 27 and FL 28 are the best candidates for the ‘midship frames,’ (although such a concept may not have been used by YK 14’s builders). Of these two floors, the curvature of FL 28 is probably more accurate due to the breaks in the long arm of FL 27. FL 29’s ‘long arm’ must have been a similar size as FL 28’s, but this part of the frame is lost, while FL 30’s ‘flat’ section is noticeably shorter than that of FL 28.

[368] Steffy 1994, 88-91, 97-100.

The midship frames do not appear to be control frames erected in an early stage of hull construction to aid in determining the shape of the hull. All four have coaks driven into the hull planking under their locations, which would have been extremely difficult to do if the floors were already in place. Score marks occur at the edges of FL 25 (on plank PS 8-2 at both edges of the floor location), FL 26 (on planks SS 7-2, SS 6-2/1-1A), and FL 27 (on plank PS 7-2), indicating that the planking to the turn of the bilge was in place before these floors were installed. Additionally, of these four floors only FL 26 was nailed to the keel. It appears that the shipwright chose an approximate area of about one meter in length for the maximum beam of the ship, but did not rely on frames to predetermine any aspects of the bottom of the hull.

Floor/Futtock Scarfs

YK 14's futtocks were scarfed to the floors in an unusual way. The inboard ends of futtocks were cut into bevels in order to fit tightly into scarf ends cut into the 'short arm' ends of the floors (**Figure 3.162**).

Figure 3.162: Floor/futtock scarf between floor FL 21 and futtock F 21.

A thin, protruding section was usually left in place on the outboard section of the floor at the scarf's location; these protrusions are quite delicate, serve no structural purpose, and could not be easily produced outside of the hull. These features were probably made by sawing with a small handsaw inside the hull (an adze or chisel would have caused more damage to the floor ends) although no damage from the ends of a saw were found along the bilge planks. Unfortunately, the original surfaces of many of the scarf ends were damaged by wood rot, so that tool marks are not clearly distinguishable on these protrusions. Where they are preserved, they indicate that the vertical faces of the floor scarfs were often sawn, but others exhibit adze or chisel marks, probably from trimming the scarf surfaces after the initial sawing for a tighter fit between the floor and futtock (**Figures 3.163-65**). The horizontal faces of the scarf ends showed more variation. Some were cut smooth and display visible adze or chisel marks (again, probably from trimming of the scarf face after the initial sawing of the scarf), while others were roughly shaped by multiple saw cuts or splitting. The inboard ends of the futtocks were cut with smooth bevels on their inner faces, well-preserved tool marks on the futtock ends show that they were shaped with an adze or chisel (**Table 3.12**).

Figure 3.163: Horizontal face of futtock scarf on floor FL 23, damaged by wood rot.

Figure 3.164: Horizontal part of the floor/futtock scarf on FL 20. Note the cut marks and the treenail that was partially cut at the right corner of the notch.

Figure 3.165: Tool marks, probably a series of angled saw or chisel cuts, on the horizontal face of the floor/futtock scarf on FL 28.

The scarf ends are sometimes cut through treenails fastening the floors to the planking, another sign that the floors must have already been installed in the hull when the futtocks were inserted. Cut treenails were found in the scarf ends of FL 15, 16, 18, 20 and FL 37. In many other cases the floor and futtock timbers are fastened at the location of the scarf end with a treenail or (rarely) a nail, but the fasteners are used to fasten the futtock to the planking rather than the floor to the futtock.

Table 3.12: Floor/Futtock Scarf Details

Floor No:	Tool Marks—Vertical Face:	Tool Marks—Horizontal Face:	Notes:
FL 4	Flat—sawn?	Flat—sawn?	No clear tool marks, but smooth surfaces: probably sawn
FL 5	No tool marks	No tool marks	No clear tool marks, but smooth surfaces: probably sawn
FL 6	--	--	No floor/futtock scarf preserved
FL 7	Cut marks—adze?	--	
FL 8	--	--	No floor/futtock scarf preserved
FL 9	Adzed or chiseled	None preserved	
FL 10	No tool marks preserved—sawn?	No tool marks preserved—sawn?	
FL 11	Adze marks	1 possible adze mark	
FL 12	Adze marks	Adze marks	Horizontal face is split, probably with a chisel or adze
FL 13	Adzed or chiseled	None preserved	
FL 14	Sawn	Adze mark	Cleanly cut
FL 15	Adzed	Damaged	Very little of the horizontal section of the scarf survives
FL 16	Sawn	Adzed/chiseled?	Horizontal face does not preserve much surface detail
FL 17	Adzed	Adzed	
FL 18	Chiseled/adzed?	Adzed	Vertical face is badly damaged
FL 19	Adzed	Adzed	
FL 20	Damaged	Adzed	
FL 21	Sawn?	None preserved	
FL 22	Sawn	None preserved	
FL 23	Sawn	Smooth—sawn or adzed	
FL 24	Sawn	Smooth—sawn or adzed	
FL 25	Sawn	Damaged surface	

Table 3.12, Continued

Floor No:	Tool Marks—Vertical Face:	Tool Marks—Horizontal Face:	Notes:
FL 26	Sawn (damaged)	Adzed or chiseled	Deep saw cut at middle of scarf
FL 27	Sawn		
FL 28	Sawn	Multiple saw cuts(?)	Very rough horizontal surface with many cuts
FL 29	Damaged	Damaged	
FL 30	Sawn	Sawn	
FL 31	Sawn	--	Horizontal section of scarf broken off in antiquity
FL 32	Sawn	Adzed	
FL 33	Sawn	Sawn (damaged)	
FL 34	Sawn	Adzed/chiseled	
FL 35	Sawn (damaged)	Adzed?	One possible adze cut visible on horizontal face
FL 36	Damaged	Damaged	
FL 37	Sawn	Sawn??	
FL 38	--	--	Floor/futtock scarf end on 'short arm' does not survive
FL 39	Sawn?	--	Horizontal section of scarf did not survive
FL 40	Sawn	Adzed/chiseled	
FL 41	Sawn	Adzed/chiseled	
FL 42	Sawn	Sawn	
FL 43	Adzed?	Adzed	
FL 44	Adzed/chiseled	Adzed/chiseled	Port 'L' shaped scarf is very small and roughly cut. Starboard scarf is a very finely cut hook scarf. FL 44 is the only floor with a scarf on both ends
FL 45	Adzed	Adzed or chiseled	
FL 46	Adzed or chiseled	Adzed or chiseled	Crudely cut scarf with minimal surface detail surviving
FL 47	Sawn (damaged)	Damaged	Horizontal section and part of vertical section of scarf did not survive
FL 48	Adzed/chiseled	Adzed/chiseled	Crudely cut scarf with minimal surface detail surviving

The reason for cutting these scarf ends is unclear. It required a significant amount of effort to produce the notches, in what must have been tight quarters, in order to create a relatively weak scarf connection that could not stand unsupported. Perhaps the shipwrights wanted additional reinforcement to the relatively weak area at the turn of the bilge, as well as frames more robust than the 'long arm' ends of the floors to reinforce the sides of the hull to the waterline. If this is the case, then the structural role of the futtocks is similar to that of standing knees or short half-frames in other vessels, although the floor/futtock scarfs in YK 14 seem more elaborate than is necessary for this type of hull reinforcement.

Towards the ends of the hull, the methods used to shape V-shaped floor timbers differed in some respects from floors in the hull's main section. FL 44 was adzed on all faces, while FL 45 was sawn on its forward and aft faces. The inner face edges of the floors FL 43-46 and FL 48 in the bow were cut with single roughly-adzed bevels rather than the more complicated beveling on the frames in the main body of the ship and at the stern. The framing pattern of alternating long- and short- arms on floors scarfed with matching futtocks, was followed at the ends of the hull as well—with the single exception of FL 44—although some of the scarf ends on the floor timbers at the extremities of the ship were very crudely made.

Limber Holes

All but one of the 45 surviving floor timbers was provided with a pair of limber holes on either side of the keel. Limber holes were made in two different ways. The more common type has straight, sawn sides and a rounded, arch-like top (**Figure 3.166**). The straight sides of these limber holes were cut with a saw while the rounded top section may have been shaped with a chisel or perhaps several drilled holes (clear tool marks generally do not survive in the upper sections of the limber holes) (**Figures 3.167-68**).

Figure 3.166: Forward face view of the limber holes on FL 38, which are typical of the limber holes on most of YK 14’s floor timbers.


Figure 3.167: Outer face view of limber holes on FL 38. Note the keel nail concretion in the pilot hole at center.


Figure 3.168: Forward face view of limber holes on FL 29. The port limber hole (right) was expanded to fit over the inner face of the keel.

These were the standard type in the main body of the ship, and were cut on 37 of the 43 floors with surviving limber holes. Rounded limber holes range from 2.0 to 3.8 cm wide and from 3.9 to 4.3 cm deep. The rounded limber holes on seven of the floors in the central section of the ship (FL 22, 23, 29, 30, 32, 33, and 35) show evidence of being crudely widened to widths of 4.2 to 5.2 cm. The concave tool marks in the limber hole suggest two possibilities for how these holes were cut: a gouge with a curved or crescent-shaped cross section was used, or else a series of holes were drilled with a bow drill and the excess wood was removed with a chisel afterwards (**Figure 3.169**). These ‘expanded’ limber holes, as well as the slight variations in the distances between the limber holes on individual floors, seem to indicate they were cut before the floors were installed in the hull, and that their positions were not necessarily measured in a very precise way.

Figure 3.169: Oblique view of the expanded limber hole on FL 29.

The limber holes on the floors were aligned in the hull in a particular way. The inboard edges of the starboard limber holes were closely aligned with the starboard edge of the keel's inner face, while the 'expanded' limber holes appear only on the port side of the frame, and were much more crudely-shaped; the other limber holes on the port sides of the floors are misaligned on nearly all of the floor timbers. Because the limber holes were cut at varying distances from each other, only the limber holes on one side could be closely aligned with the edge of the keel's inner face. The 'expanded' limber holes were widened because they were cut on certain floors before they were installed and were thus too close together to fit over the protruding inner face section of the keel (**Figure 3.170-71).**[369] The limber holes may have been lined up on the starboard side of the keel for a functional reason; perhaps it made the process of shaping pairs of floors simpler. Although the floors were shaped in a fairly standardized way, measurements seem to have been approximate for the limber holes and likely other features as well, such as the total length of the floor timbers and their exact curvature in the hull.

[369] This contrasts with Steffy's reconstruction of the projection of the Serçe Limanı ship's frames, in which limber hole locations are part of the planned design (Bass et al. 2004, 155-56).

Figure 3.170 Alignment of limber holes on FL 29 over the keel before its removal from the hull. The port side and the ‘expanded’ limber hole are to the left.

Figure 3.171 The limber holes on FL 33 in situ, viewed from the aft sawn face of the floor. The starboard limber hole is closely aligned with the starboard edge of the keel, while the port side limber hole required re-shaping in order to fit over the port side of the keel’s inner face.

Limber holes on six of the floors at either end of the ship were triangular in shape (FL 4, 5, 43, 44, 45, and 46); they were cut with an adze or chisel, and the forward and aft face edges of the cuts were usually chamfered. Limber holes of this type ranged in width from 2.4 to 3.8 cm wide and 1.0 to 2.8 cm deep. One surviving floor timber, FL 48, was notched over the keel but did not have limber holes, apparently because it was high enough in the hull not to require them (**Figure 3.172**). Another unique floor timber is FL 46. Triangular limber holes were cut in the area of SS 1, probably before the timber's final location in the hull was chosen, and a shallow depression was cut in the area where the frame was finally fastened to the keel. A shim or wedge was fastened between the floor timber and the planking in the SS 1 area so that the floor could be solidly fastened to the garboard strake (**Figure 3.173**).

Figure 3.172: FL 44-48 in situ. Displaced floor FL 48, in the foreground, has been moved back to its original position for the photograph. The wedge or shim below FL 46 is visible under the limber holes cut over SS 1-3.

Figure 3.173: Forward face of FL 46. Note the limber holes and wedge (fastened in its original position) in the port garboard (SS 1) area of the outer face of the floor. The keel area of the floor is a shallow cut depression to the left of the limber holes in the photograph.

Frame Fasteners

The frames are fastened to each strake with one to three treenails; one or two treenails is typical, depending on the width of the plank and its location in the hull. Iron nails were typically used singly, although in a few instances two nails were used as frame fasteners at a single strake, usually as repairs. Evidence from the surviving floors and fastener holes in the inner faces of the keel timbers indicate that 20 or 21 of the estimated 51-52 floors were nailed to the keel.[370] No treenails were used to fasten floor timbers to the keel. The keel nails were driven through pre-drilled pilot holes, which penetrate the thickness of the floor timber from the inner to the outer face; no evidence of treenails were found in these holes, which instead contained nail shafts and iron concretion. On 14 of the 19 surviving floors nailed to the keel (FL 9, 12, 14, 17, 20, 23, 26, 29, 38, 41, 43, 45, 46, and 47), a recess was cut in the inner face for the nail head (**Figures 3.174-75**). Some are too small and deep to have been cut with anything other than a chisel, but, in a few cases (FL 9, 45, and 46), the wide and shallow countersinking was probably cut with an adze. The countersunk areas range in length from 2.2 to 6.6 cm, in width from 2.2 to 5.3 cm, and are from 0.3 to 1.2 cm deep. The remaining keel nails were driven without countersinking recesses for the nail heads, although some of the nail heads left impressions in the inner face surfaces of the floors.

[370] Surviving floors fastened to the keel timbers include FL 6, 9, 11, 14, 17, 20, 23, 24, 26, 29, 32, 35, 38, 41, 43, 45, 46, and 47. The frame locations of FL 49, 51, and 52 are based on planking and keel fasteners only. FL 44 has a nail hole in the keel under the floor but was not fastened to the keel itself; this and other evidence of fasteners and the frame's unique shape suggests that it may be a repair piece, or the nail was a temporary fastener used during construction.

Figure 3.174: FL 12, keel nail concretion on the inner face.

Figure 3.175: Location of the inner face of the keel nail on FL 12, after removal of iron concretion. Note the nail head impression and the cut countersink for the nail head.

Figure 3.176: Nail concretion in a clearly-defined pilot hole on the outer face of FL 12.

FL 44: A Possible Repair Floor

Several features of FL 44 and its location in the hull are unique, suggesting its possible origin as a repair component. FL 44 is the only floor timber with scarfs on both its port and starboard ends. The port end is cut into a somewhat crude L-shaped floor/futtock similar to those seen on nearly all of the other surviving floor timbers, while its starboard end terminates in a 17 cm-long hook scarf, the only one of its kind used in the ship on frame timbers; this scarf joined futtock F 44, now lost (**Figures 3.177-78**). FL 44 is the only frame from YK 14 with no sawn faces; all of its faces were worked with an adze. A nail hole on the inner face of the keel under FL 44 does not correspond to a fastener on the frame, but it is aligned with several caulked drilled holes in planks PS 1-2 and SS 2-2 in the area of the frame. This suggests that a futtock or frame (either a temporary cleat used during construction or an original frame that was replaced by FL 44) may have been previously installed in this area of the hull. A row of caulked holes in the planking between PS 10B, 10A, and PS 12-2 are located just forward of the fasteners for the missing futtock F 44; these indicate that another futtock or the ‘long arm’ of a floor was once found in this location as well. If FL 44 corresponds to a later repair, it is possible that some of the original fastener holes for the treenails were used to fasten it in place, since there are not enough ‘blind’ fasteners in the planking at this frame. It seems more likely that FL 44 was the only available compass timber with the correct curvature for this specific location in the hull during construction, and was scarfed to a futtock on the starboard side because a longer floor timber was unavailable.

Figure 3.177: Hook scarf on the starboard end of FL 44. Note the caulked holes in the planking just forward of FL 44.

Figure 3.178: Oblique view of the hook scarf on the starboard end of FL 44.

Mast Step Mortises

FL 22 and 28 each have mortises cut out of one side of the inner face of the frame over the keel **(Figure 3.179)**. On FL 22, the notch is 13.0-13.3 cm long, 3.4-3.6 cm wide, and 3.1 cm deep, and is cut into the inner face/forward face edge of the frame. On FL 28, the mortise is 11.7 cm long, 2.7-3.7 cm wide and 3.8-3.9 cm deep, and cut into the inner face/aft face edge of the frame (**Figure 3.180**). These mortises were cut for the ship's mast step, and their placement give a minimum length for this timber of approximately 1.39 m (see Chapter V for a reconstruction of this timber). Like the mast steps from most of the Yenikapı shipwrecks, YK 14's mast step was not nailed to the floors; for this reason, it probably floated away during the ship's sinking, or was salvaged soon afterwards. No evidence for a mast partner was found in the hull in this area, but the occurrence of the mast step notches approximately amidships is consistent with a single-masted lateen rig (see Chapter V).

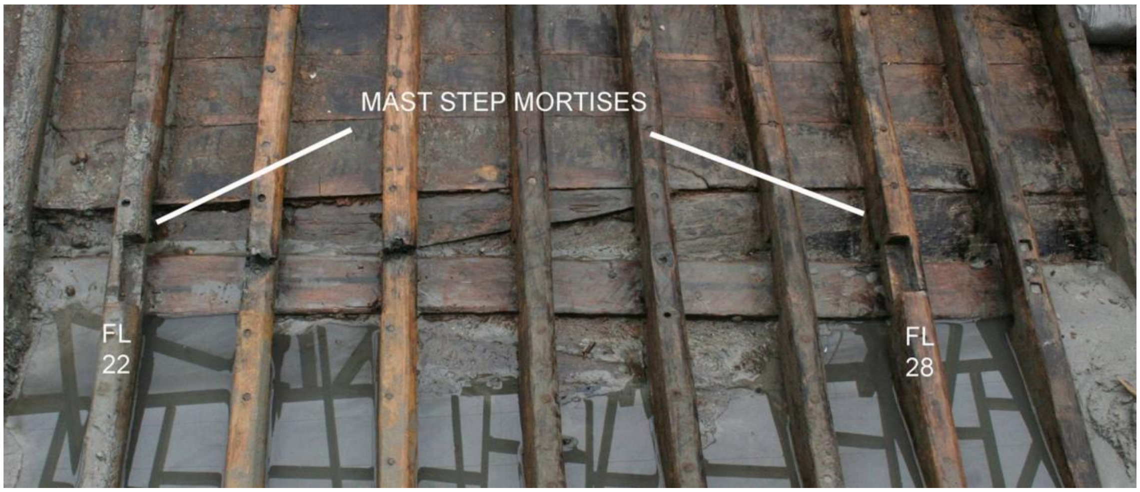

Figure 3.179: Mast step mortises in FL 22 and FL 28.


Figure 3.180: Detail of the mast step mortises in FL 28.

In an excavation photo of the floors FL 21-23, two parallel ridges appear on the inner face of FL 21 over the keel area. These impressions appear to be pitch ridges on the inner face of the floor built up at the original edges of the mast step's location, and indicate that the mast step may have extended beyond the mortises in FL 22 and 28 (**Figure 3.181**). No such feature is visible in the post-excavation photographs of the timber or was observed during the drawing and cataloging of the frame, probably because the pitch was washed off during the excavation.

Figure 3.181: Pitch ridges on either side of the keel area of FL 21 (center), suggest that the mast step extended beyond the mortise in FL 22 at right. This feature was washed off the timber over the course of the excavation.

Stanchion, Bulkhead, and Through-beam Locations

Pairs of mortises occurring in floors FL 29, 32, and 37 over the keel are most likely intended for inserting stanchions at these locations (**Figure 3.182**). The mortises are roughly square in section, 2.2-2.7 cm to a side, and 1.2-2.0 cm deep. They were cut on either side of the location of a keel nail on FL 29 and FL 32. The lower ends of the stanchions were not fastened to the floor timbers with treenails or nails.

Figure 3.182: Mortises for stanchions on the inner face of FL 29, located over the keel area. A drilled hole and a countersinking for the keel nail head is visible between the mortises).

At FL 29 and FL 32, the stanchion mortises correspond to the locations of through-beam holes cut into PS 14 just aft of the futtocks F 29 and F 37. These futtocks have grooves cut into their inner faces with chisels, presumably for planks forming a removable bulkhead (**Figures 3.183-84**). The grooves in the inner faces of F 29 and F 37 are 1.5-2.5 cm wide, which indicates that the bulkhead planks were likely at least 1.0-1.5 cm thick, although the ends could have been thinned to fit in the groove. A roughly-cut depression in the aft face of F 29 in the PS 13-14 area apparently accommodated a through-beam, which may have already been inserted at the time F 29 was installed. The bulkhead futtocks were fastened to the hull primarily with treenails; they were driven into drilled holes that had been angled towards the forward face of F 29 and towards the sawn aft face of F 37 in order to avoid the groove in the inner face of the timber (**Figure 3.185**).

Figure 3.183: Groove cut in the inner face of F 29 for a bulkhead.

Figure 3.184: Detail of the groove cut in the inner face of F 29.

Figure 3.185: The forward face of F 29, a futtock with a groove in its forward face for a bulkhead. Note the angled treenails which were cut flat on the timber's forward face.

No fastener holes relating to the bulkheads were identified in the frames, which suggest that they were removable. Since stanchion mortises and through-beam holes appear in the same areas at FL 29 and FL 32, it is likely a third through-beam was fastened above PS 13 at FL 37, where the planking did not survive. Through-beams in the hull must have been used to support partial decks at the ends of the ship, although the F 29 through-beam near amidships was likely used as a mast partner beam.

Futtocks and Top Timbers

Seventeen futtocks were preserved wholly or in part in the hull; the eight complete examples range in length from 75 to 104.5 cm.[371] The lower ends of the futtocks were scarfed into the floor timbers between strakes 6-8, depending on their location in the hull. The upper ends of the futtocks terminated around PS 14 or 15, one or two strakes after the first wale PS 13 and at the level of the ship's waterline.

[371] This does not include F 19 and F 33, which may be complete futtock timbers but have badly damaged upper ends.

In addition to the futtocks preserved in the hull, a second set of futtocks or top timbers must have been present to support the bulwarks and upper part of the hull. These frames probably extended to the ship's caprail. Multiple treenails, as well as other evidence such as pressure marks from frames and pitch deposits, indicate that up to ten or eleven frames were fastened between approximately every fourth frame, between FR 11-2, 15-6, 20-21, 24-5, 29-30, 32-3, 36-7, 37-38, 39-40, 40-41, and 43-4. Top timbers at these locations supported the upper works of the ship from the waterline to the caprail. The closer spacing of the top timbers between FL 39 and FL 44 may have been due to the large number of scarf seams and repairs in this area.

Stringer ST-1

A long section of a stringer, ST-1, was also preserved on the port side, parallel with PS 14, the highest remaining strake in the hull (**Figure 3.186**). ST-1 was shaped from a small-diameter pole or trunk of beech (*Fagus orientalis*), with approximately 2.29 m of the timber's original length preserved. The timber ranges in width from 6.1 to 8.4 cm wide and is 2.6-3.1 cm thick.

The extant section of the stringer runs from futtocks F 21 to F 31, and was fastened to every second frame with single treenails and one nail at the surviving aft end. Stringer ST-1 was fastened only to futtocks, which have larger cross-sectional dimensions than the ‘long arms’ of the floor timbers in this area of the ship. The stringer fasteners were driven from the inside of the hull, since the larger diameters of the treenails were located on the inner faces of the stringer and futtocks; a nail head impression was also found at a nail hole on the inner face of the stringer at futtock F 31. Both ends of ST-1 had broken off at fastener holes, an indication that the original timber was longer. Fastener holes on the inner faces of futtocks forward and aft of ST-1 indicate that the stringer probably extended from at least F 19 to F 35, which correspond to an approximate minimum length of 3.8 m. The chamfered inner face edges of the stringer were probably shaped with an adze, although few clear tool marks survived, while the flat outer face was sawn.[372] The function of this stringer is unclear. It is rather light and would not have provided much additional longitudinal support, and its location in the hull is also too high to be effective as ceiling planking for use with the ship’s cargo. It may have been used as a step or as a cleat inside the hull.

[372] On YK 1, a 6.24 m-long stringer of similar dimensions and cross-sectional shape was found in the same location as ST-1 on YK 14.

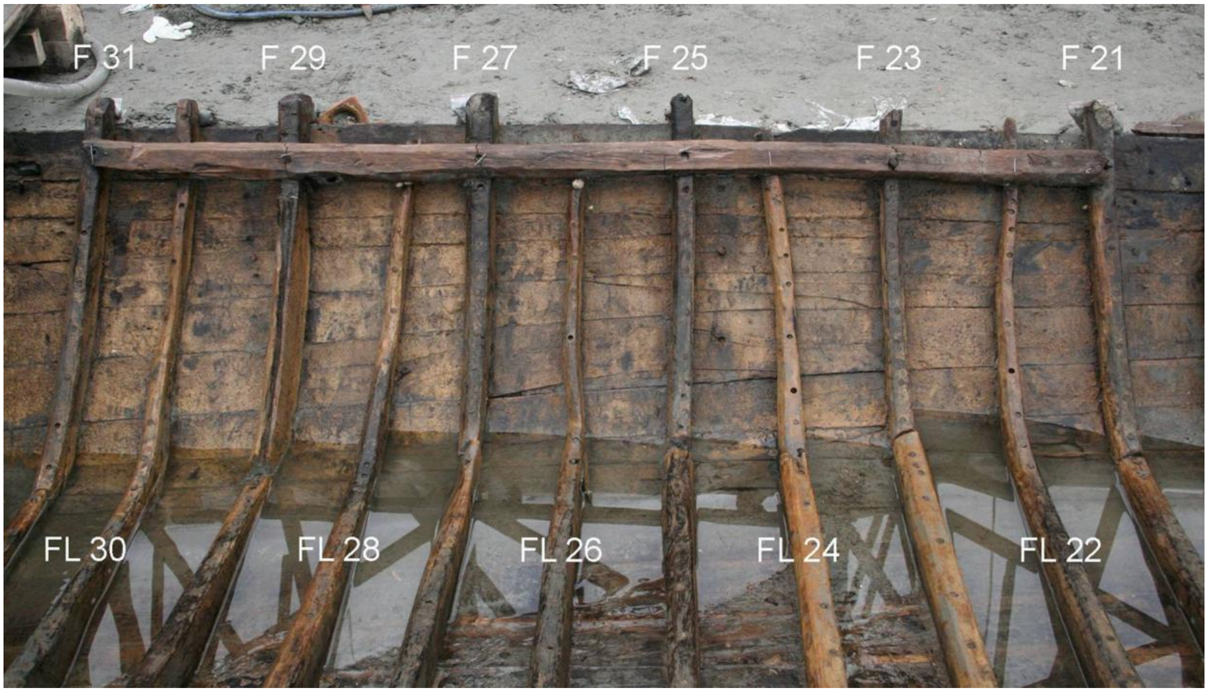

Figure 3.186: Stringer ST-1 in situ, with frames labeled.

Possible Evidence for Stringer or Ceiling Planks

Fasteners and fastener holes not used for fastening planking to the frames were discovered on the inner faces of a number of frame timbers. Often these are holes drilled from inside the hull which do not penetrate the full thickness of a frame, or, in instances where they do reach the frame's outer face, do not penetrate the planking below. A few examples exhibit iron stains or contain iron corrosion products, suggesting that they were pilot holes for iron nails. These fasteners are generally scattered throughout the interior of the hull in no discernible pattern, with the possible exception of a concentration of the fasteners at the turn of the bilge area on the starboard side at strakes PS 5, 5A, and 6. It is possible that a stringer was fastened in this area, although distinguishing stringer or ceiling plank fasteners in the hull from repair fasteners is in some cases difficult, particularly in the heavily repaired turn of the bilge area on the starboard side. If stringers and ceiling planking were present in the hull, it seems they were fastened in very few places and did not play any role in reinforcing the hull structurally.

In addition to the presence of empty fastener holes inside the hull, there are also pressure marks or pitch ridges on the inner faces of some floor timbers which could have been made by ceiling planks or other internal timbers. One pressure mark occurs on FL 40 around strakes PS 1 and PS 2, and is about 7 cm wide. Another occurs on the inner face of FL 23 in the SS 1-SS2 area and is about 7.7 cm, with cut marks visible at the edges of the impression (**Figure 3.187**). If ceiling planking were used, they were likely loose planks that floated off after the sinking of the ship, or the ship's cargo was laid directly on dunnage over the ship's ballast.

Figure 3.187: Cut and pressure marks on the inner face of FL 23 possibly related to ceiling planking or other internal timbers.

6) Unidentified Members (UM) from the Shipwreck Site

Nineteen UM timbers were recovered during YK 14's excavation, most of which are identifiable as specific types of ship timbers.[373] The UM timbers have been divided into several categories, including frames, planks, 'Miscellaneous' timbers, and rigging elements. These categories do not include in-situ dock pilings, which date to a later period than the shipwreck and were numbered separately. Several UM numbers (UM 6, 10, 11, and 16) were deleted after they were joined to other hull timbers or their original locations were identified in the hull of the ship. The UM rigging elements are described in Chapter V, while the 'Miscellaneous' UM timbers are not included in the catalog due to their doubtful attribution to the shipwreck and lack of significant characteristics.[374]

UM Frame Fragments:

UM 2, 3, 8, 15, 17, 19, 21, and 22 are frame pieces found on the shipwreck site. All of the timbers except UM 15 and 17 share many features with YK 14's floors and futtocks and, based on where they were found, are almost certainly from the ship. These frame pieces are probably from the missing starboard side or upper section of the hull. All of the UM floor pieces were made of Turkey oak (*Quercus cerris*) except for UM 15 and UM 17, which were made from Sycamore maple (*Acer pseudoplatanus*).

[373] These timbers were labeled UM 1, 2, 3 (UM 6 was joined to UM 3), 4, 5, 7, 8, 9, 12, 13, 14, 15, 17, 19, 20, 21, 22, 23 and 24.
[374] UM Planking fragments which are not described in this chapter are UM 14 and 18. The Miscellaneous UM timbers include UM 1, 4, 7, 8, 9, 13, and 20; of these timbers, only UM 13, a teredo-worm-infested timber with a bolt concretion, is potentially a hull timber, and is almost certainly not from YK 14.

UM 2, 3, 19, and 22 resemble the tapered ends of ‘long arms’ of floor timbers located along most of the starboard side of the shipwreck. As with the floors and futtocks from the ship, the molded sides of these UM pieces consist of a flat, sawn face and a rounded, adzed face. UM 2, 3, and 19 were almost certainly from the ends of floors on the starboard side of the ship based on these orientations. UM 2 was found in a gap between strakes SS 6 and 7 between floors FL 39 and FL 40, while UM 3 (to which UM 6 was later joined) was discovered just aft of the port end of FL 38. UM 19 was discovered under plank PS 3-1 in the stern area around FL 3 and FL 4, while UM 22 was found on top of the keel inside the hull between FL 4 and FL 5.

UM 8 is an unusual, small timber with a sawn ‘outer face’ and rounded ‘inner face’ (**Figure. 3.188**). Several drilled holes in the piece may be for treenails, but it is too flimsy to have contributed much structural strength, and seems to be too narrow to have been from a stringer or ceiling plank. UM 8’s function is unclear; perhaps it is a repair to a cracked section in a frame (?). UM 8 was found 40-60 cm from the outboard edge of FL 36 and SS 6-3.

Figure 3.188: The inner and outer faces of UM 8.

UM 15, 17, and 21 are probably parts of futtocks or top timbers based on their overall shape, while UM 19 is a floor end, probably a ‘long arm’ end from one of the floors. Both UM 17 and 21 were discovered under the hull, and are likely from the upper works of the ship.[375] Both have a narrower, beveled end and a thicker, broken opposite (inboard?) end. UM 21 resembles the preserved starboard-side futtocks in having one flatter, sawn molded face and an opposite face with three chamfers on the inboard edge.

[375] UM 17 was found next to FL 47, under the keel/garboard area in the bow, and may have originated in the bow area of the hull. UM 21 was found at the stern, under the aft end of PS 3-1, between FL 3 and FL 4.

UM 17 lacks the sawn face seen on nearly all of the frames on YK 14, and retains single chamfers on the timber's inner face edges. Both pieces have a shape different from the in-line futtocks preserved in situ on the wreck. The angling of the outer face of UM 17 suggests that it originates from near the end of a vessel rather than towards amidships. Both UM 17 and 21 were fastened only with treenails.

UM 15 is a 95 cm-long complete futtock, adzed on all faces, and roughly chamfered on its inner face edges (**Figures 3.189**). It was found in three pieces approximately 1.6-2.0 m north of the ship's bow during digging of a ditch to drain water from the wreck site. One end of the futtock retains a shallow notch. This piece may also be a top timber, probably from the center of a ship's hull based on the angle of the outer face surface. However, the frame's unusual features as well as the fact that it was found further away from the hull than most of the other UM timbers seem to suggest that an origin from another ship is likely.

Figure 3.189: The inner face of UM 15.

Planking UM Timbers (UM 5, 12):

UM 5 is a 26.5-cm long section of a diagonal scarf of a plank of Sessile oak (*Quercus petraea*) (**Figure 3.190**). A countersink was chiseled out on the plank's upper edge and a pilot hole drilled for toenailing the scarf. This method of scarf fastening was not found elsewhere on YK 14. Thick pitch deposits on Face 'A' (found face-up on the site) suggest that it is the outer face of the plank. UM 5 may be the original forward end of PS 6 or a higher strake based on the location of its discovery, outboard of FL 4's starboard side.

Figure 3.190: Countersinking cut for toenailing the scarf tip of UM 5.

UM 12 is a hull plank fragment of Turkey oak (*Quercus cerris*) measuring 122.8 cm in length and with a maximum width of 25.1 cm (**Figure 3.191**). UM 12 was cut from a large log; approximately 95-105 rings are visible in the area of the S-scarf between frame locations 'B' and 'C'. Despite the context of the find, UM 12 was sampled for dendrochronological analysis due to its large number of tree rings, which was very unusual for hull planks from YK 14. Perhaps wider planks from trees of a more advanced age could be used in the hull above the waterline due to the simpler shape and curvature in this area of the hull.

UM 12 is unusual in having no coaks or coak holes in the plank edges, a strong indicator that it came from the upper part of the hull above the waterline. The inner and outer faces of the plank can be identified based on the heavy pitch deposits and larger fastener diameters on the original outer face. A cut raised area occurs at frame location ‘C’ on the inner face of the plank, a feature seen only on upper strakes PS 13 and PS 14, which were not edge-fastened in the hull. UM 12 was found under the after end of the hull on the port side. Both edges are cut, presumably for a scarf; Edge ‘D’ of the plank was cut for a partially preserved S-scarf 38.0 cm long, which probably had an original length of at least 60 cm. Edge ‘C’, the opposite edge on the same end of the plank appears to have been cut for a three-planed-scarf or an inset plank such as a stealer (closer to End ‘A’). Fastener holes and pressure marks from the edges of frames indicate that five frames, almost certainly all futtocks, were fastened to the plank. The frames were fastened almost entirely with treenails driven from the outside of the hull. On the inner face of the plank at the location of Frame ‘B’, a caulked drilled hole with what appears to be a nail head impression was found, probably for fastening a temporary frame or prop used during construction.

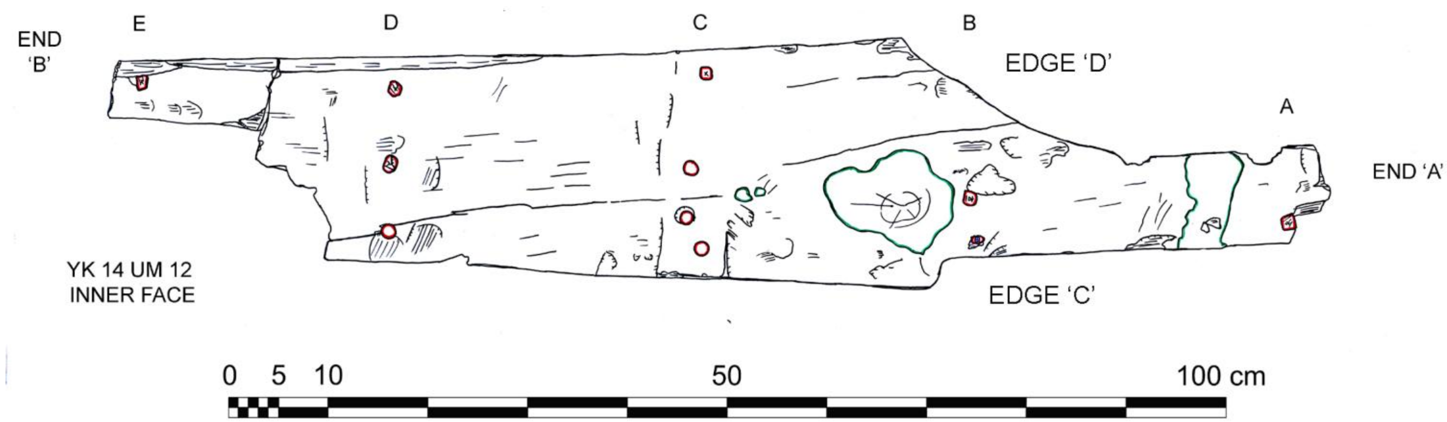

Figure 3.191: Inner face of UM 12.

CHAPTER IV

A RECONSTRUCTION OF THE HULL

Yenikapı 14 is a well-preserved shipwreck by archaeological standards, but approximately two-thirds of the ship, including its internal structures and necessary sailing equipment are missing. Because so much of the ship is lost and significant distortion of the hull timbers may have occurred after sinking, every feature of the reconstructed hull is added based on varying degrees of certainty. Many structural features, especially from the bottom of the hull, are well preserved and present few difficulties in interpretation. Other features are postulated based on indirect evidence from better preserved sections of the hull; for example, the presence of stanchions and bulkheads based on mortises and grooves in frame timbers and through-beams based on holes cut in the planking. Still other features are added based on **a)** analogy to other shipwrecks as well as artistic depictions of Byzantine ships, **b)** analogies to ethnographically-documented vessels of later periods, and **c)** educated guesswork. Some features are added simply because they would have been necessary—for example, cleats or pins for belaying lines in certain areas of the ship—even though little or no evidence survives for how and where such features appeared on a tenth-century Byzantine vessel. These aspects of reconstruction were avoided whenever possible since these are the most debatable and subject to change; they are noted throughout the text, and an explanation is given for assuming their presence in the reconstruction. The tools and basic methods available for shaping timbers in the medieval Mediterranean were described in Chapter

III; the construction sequence of the hull and a proposed reconstruction of the vessel are presented here.

1) Construction Sequence of the Lower Hull

The ship was probably built by a single master shipwright with one or a few assistants, occasionally supplemented by help from specialists such as sawyers, blacksmiths, and caulkers.[376] As the literal backbone of the ship, the first timber to be shaped and laid was Keel 2, the central keel timber. The shipwright selected a large, straight oak timber and laid it on stocks. The stocks were probably some distance from the ground, based on the necessity of driving fasteners from the outside of the hull; or, pits may have been dug under the keel in order to drive fasteners upward.[377] Some fastener holes in the sides of the keel timbers that are located below the level of the garboard strakes are most likely traces of fasteners used to affix stocks or propping timbers to the keel. The finishing of the keel timber, including the cutting of the rabbets on the port and starboard sides, probably occurred at this time or shortly beforehand. The keel timbers and end-posts could have been laid on the ground on their port and starboard faces, respectively, in order to cut the rabbets before they were propped and fastened in place parallel to the ground with their inner faces oriented upwards. The transverse 'tow hole' on Keel 2,

[376] This follows ethnographic accounts of the construction of the construction of similarly-sized vessels (Greenhill 1971, 72-4; see also Beckerleg 2002, 265-76). Byzantine-era shipbuilding, at least of smaller vessels, was probably also very loosely organized; there is no evidence for shipwrights' or shipowners' guilds (i.e., *navicularii*) in the Middle Byzantine period (Maniatis 2001, 344-45, n. 20).

[377] This technique is used in dhow construction in Kuwait; see al-Hijji 2001, 72. Bolts are generally fastened from below on Roman and Byzantine ships (see, for example, van Doorninck 1976, 124; van Doorninck 1982, 58), and bolt heads were sometimes countersunk into the outer faces of keel timbers on the Yenikapı ships (for example, on YK 1).

situated below and between FL 28 and FL 29, must have also been cut either at this time or after the other keel timbers were fastened to it. One possible function of the transverse hole in the keel is as a rough marker of the ship's midship area during the early phases of construction, since it is positioned at the widest part of the hull. Once desired length of the main keel timber had been established and the timber shaped, the extremities were sawn to the proper length and cut into keyed-hook scarfs so that Keel 3 and Keel 1, the curved timbers forming the transitional pieces between the keel and the stem and sternpost, could be fastened to the main keel (Keel 2).

The builders would have carefully selected compass timbers of the desired length and curvature for Keel timbers 1 and 3. The rabbets on Keel timbers 1 and 3 and possibly the transverse 'tow hole' in Keel 3 may have been cut before shaping and fastening of the scarf ends. Cutting the scarf ends on the curved timbers was a laborious process, and the builders would have either propped the timbers upright or, more likely, positioned them on one side. After the scarf ends were shaped to the builder's satisfaction, Keel timbers 1 and 3 were fastened to Keel 2 and locked in place with wooden scarf keys. One of two holes for fasteners may have been drilled into the forward scarf of Keel 3 at this stage, probably for securing the stem-post with an iron bolt.[378] The scarf connecting Keel 1 and 2 was shaped in an unusual manner, probably due to a mistake occurring during the cutting of the timber: the inner faces of the two timbers at the scarf were not cut flush,

[378] Or, a stemson could have been fastened here similar to the longitudinal timbers affixed over the frames on YK 11 and 23 (see Chapter VII). This seems less likely since a similar timber on YK 23 was nailed in place onto floor timbers, as were the stemson and sternson on YK 11.

and the shipwright inserted three scarf keys in the scarf instead of a single key as in the other keel scarfs.

It is possible that the keel timbers were cut to specific lengths based roughly on the Byzantine foot of 31.2 cm.[379] The length of the main keel timber, Keel 2, is 6.55 m, or 20.99 Byzantine feet long. Keel 3, which is 3.45 m long, is approximately 11 Byzantine feet long. Keel 1 is 6.28 Byzantine feet, and may have had an intended original length from anywhere between 6 1/3 to seven Byzantine feet long (the exact length may have been shortened due to difficulties in cutting the hook scarf between Keel 1 and Keel 2). Scarfed together, these pieces are 11.42 m, or 36.60 Byzantine feet long. The lengths of Keels 2 and 3 are so close to multiples of the standard Byzantine foot that it seems likely that these two timbers were measured and cut using this measurement standard.

In later periods, ships' hulls were often built to proportions in which the length of the keel, the total length of the ship, the ship's beam and depth of hold were all related to specific formulas or sets of rules, which were sometimes explicitly stated in shipbuilding contracts.[380] Although these formulas were used for frame-based ships, some simple proportions at least were probably used in shell-based construction as well. Textual references to ships since classical antiquity indicate that merchant ships were categorized

[379] Schilbach 1970, 13-6.
[380] Steffy 1994, 93, 96-100; see also Barker 1991; Rieth 2003; Alertz 2003; Hocker and MacManamon 2006, 2-3, 7-8, 13; Loewen 2007, 3-11. These sets of rules or instructions for construction did not necessarily relate to mathematical proportions, however, and often involved the interaction between the set of dimensions or proportions and improvisation by the master shipwright during construction, often based on the use of ribbands: see McGee (2009, 220-22, 231) and Bondioli (2009, 250-71) for an analysis of this process based on the Michael of Rhodes manuscript.

primarily by cargo capacity, and, consequently, cargo capacities were the primary determinant of the dimensions of a ship.[381] In many shipbuilding traditions, including both shell- and frame-based methods, units of capacity are used by the shipwright to calculate the basic dimensions of a vessel's hull. In the ancient world and medieval Byzantium these were usually the *modios* of liquid or the *litra* of grain.[382] In the later medieval period, the standard was barrels or dry measure units of specific capacities from specific cities or states, while in the Persian Gulf in the twentieth century, ships were built to a cargo capacity estimated based on the standard size (180 lb./ 81.8 kg) of packages of dates from Basra.[383]

The cargo capacities of Byzantine merchant vessels were occasionally recorded in documents, primarily from the eleventh century and later.[384] A thirteenth-century copy

[381] Lane 1964, 218.
[382] Several types of *modios* were in use since ancient times, for uses as varied as a measure of land to wet and dry measures (Wallinga 1964; Harvey 1989, 50-4, 238-40, 276-78). The measure used for ship capacities in antiquity was most likely the *modius castrensis*, used for grain and other dry goods (1 *modius* equaling approximately 9 liters) (Rickman 1980, xiii, 17; see also Duncan-Jones 1976; Kazhdan 1991.2: 1388; Haldon 2000, 296, n. 223). In the tenth century, the *thalassion metron*, or 'sea measure', equivalent to 30 *litrai* (1 *litrai* = 320 g), was a capacity measure used in the Byzantine Empire for liquids such as wine and oil (Kazhdan 1991.2: 1359; see also Schilbach 1970, 95-6, 112-15; van Doorninck 1993, 8-12; Pitarakis 2012, 410-16). In their studies of the capacities of amphoras from the seventh-century Yassıada ship and the eleventh-century Serçe Limanı ship, van Doorninck and van Alfen have discovered evidence for highly standardized amphora sizes for specific products (red and white wine and olive oil) in the amphoras from the Yassıada and Serçe Limanı ships (van Doorninck 1989; 1993; 1995; see also Kazhdan 1991.2: 1359; van Alfen 1996). These shipwreck finds are paralleled in contemporary sources such as the wine measures mentioned in the early tenth-century *Book of the Eparch* (Freshfield 1938, 43-4). The 'sea *modios*' or *thalassios modios*, consisting of 40 *litrai* or 17.084 liters/12.8 kg, on the other hand, was used for dry measures such as wheat, and is likely the *modios* used to measure ships' hull capacities in Byzantine documents (Schilbach 1970, 96; Kazhdan 1991, 2:1388).
[383] See Lane 1964, 218-29; Villiers 2006, 37, 367. Villiers describes an Arab shipwright's methods of constructing small dhows: "He built the dhow purely from his head. If you wanted him to build you a ship, apparently, you just told him to build you one with a capacity for so-and-so many packages of dates. He knew no other measurements" (Villiers 2006, 37). Today, sacks of rice or other grains are another unit of capacity measurement (Agius 2002, 137-38).
[384] Makris 2002, 94-5; see also Harvey 1989, 238-41; Antoniadis-Bibicou 1966, 139-40.

of an older text even gives instructions on how to measure the cargo capacity of a vessel for tax purposes based on a standard-sized basket (a *koupho*) representing six *modii* or 40 *litras* of wheat.[385] YK 14 was probably designed to a fairly specific cargo capacity; the ship's hull characteristics suggest that this design probably involved the estimate or measurement of a few basic dimensions (length, beam, depth of hold, etc.) rather than the use of pre-designed 'control frames' to shape the hull. Such design parameters must have involved much flexibility on the part of the shipwright in designing the details of the ship.[386] Despite this, the shipwrights who built YK 14 and the other coak-built ships from Yenikapı were capable of constructing highly standardized vessels based on experience and perhaps a few rough dimensions.

2) Assembly of the Hull Planking to the Waterline

After the keel and posts were erected, the next step was the fastening of the garboard strakes to the keel. The garboards were carefully shaped, especially towards the ends of the hull and along the beveled inboard edge that was to fit into the keel rabbet. This process seems to have involved extensive work with adzes and char-bending the garboards in the bow area (PS 1-2 and SS 1-3). Once the garboards were cut into the desired shape, they were propped, wedged, or clamped in place; then, they were fastened to the keel. Holes for wooden coaks and garboard nails were drilled in the garboards at an angle from the outer face near the inboard edge of the plank, through the keel rabbet

[385] Harpster and Coureas 2008, 9, 11-4, 18-9.
[386] Steffy 1994, 43; see also Agius 2002, 137-38. Hasslöf (1972, 58-60) notes that one of the main advantages to shell-based construction of the bottom of a ship's hull is the ability to spot and correct mistakes during assembly, an option not available in building skeleton-based vessels; this advantage is specifically stated in one seventeenth-century source.

and out the inner face of the keel. However, not all of the holes drilled in the inboard edges of the garboards were used, and in several locations, particularly along Keel 1, caulked-over drilled holes were found that did not match fasteners holes on the inboard edges of the garboard planks. Perhaps the holes were drilled in the garboard planks before they were fastened to the keel, and not all of them were used for fasteners; or, the positions of the garboards were changed during construction. The diameters of the inboard ends of the coaks on the inner faces of the keel were significantly smaller than their diameters on the outboard sides. Caulked drilled holes in both the keel rabbets and the inboard edges of the garboards may be due to the separate drilling of at least some of the edge fastener holes in the keel and garboards before assembly. After the coak holes were drilled in the garboards, coaks were driven from the outside of the hull until they protruded beyond the inner face of the keel, after which they were cut flush with the keel and garboard surfaces on both ends (with at least one exception at FL 14, where the coak protruded from the keel's inner face). In certain locations, nails driven through predrilled pilot holes were used to fasten the pieces, perhaps before the drilling of the remaining coak holes commenced.

The scarf ends on the port and starboard garboard planks were fastened in different ways. On the starboard (PS) side, PS 1-1 and PS 1-2 were fastened together by an S-scarf; PS 1-2 was probably fastened to the keel first, based on the inboard position of the

PS 1-2 side of the S-scarf.[387] Based on the orientation of the scarf ends on each of the four garboard planks on the port (SS) side, SS 1-2 was installed first, followed by SS 1-1/1A-5 or SS 1-3, and completed with SS 1-1/1. The unusual scarf ends between SS 1-1/1 and SS 1-1/1A-5, and SS 1-2 and 1-3, as well as the large number of caulked and abandoned fastener holes along the seam, suggest that substantial readjustments were made while fastening these pieces in the hull. Neither SS 1-1 and SS1-1/1A-5, nor SS 1-2 and SS 1-3, were attached to each other at their scarf ends. Plank SS 1-1/1 was attached to Keel 1 with a combination of coaks and hood-end nails driven through drilled holes; the plank's irregular aft (SS 1-1/SS 1-1/1A-5) scarf was roughly shaped with an adze. This is probably due to a split or break in SS 1-1/1A-5, which occurred during construction, thus necessitating the shaping and insertion of SS 1-1 as a 'construction repair' piece. Similar pieces occur in several areas of the hull planking (e.g., PS 9A and PS 14-2/1; see Chapter III). SS 1-2 and SS 1-3 are joined using a short, beveled diagonal scarf which was later caulked, but the pieces were not fastened to each other, except with a treenail driven inboard through the beveled scarf (perhaps deliberately) into the floor timber FL 38 above.

The procedure for installing hull planks past the garboards was the same for most planks up to the waterline. Planking scarf ends in the hull are generally diagonal or S-scarf ends fastened to each other by wooden coaks; based on the orientation of these scarfs and the

[387] In most cases, it appears that planks with diagonal- and S-scarf ends were fastened to the hull individually, with the plank on the inboard side of the scarf fastened first. In a few instances, the planks may have been scarfed together before attaching to the hull. This likely occurred with three planks scarfed together on strake PS 14 (PS 14-1, PS 14-2/1, and PS 14-2/2-6).

presence of coak joints along the plank seams, the construction sequence of the hull to the waterline can be reconstructed. The installation of a hull plank consisted of several stages. At an early stage of the process (probably when the next hull plank had been roughly shaped), coak holes were drilled in the upper edge of the previous strake fastened to the hull. The coak holes were usually drilled to a depth of 5-8 cm and spaced at intervals of approximately 25-50 cm, with an average spacing of 39 cm. The coak spacing varies sufficiently to indicate that their locations were unlikely to have been pre-measured in any way, although a rough standard of spacing coaks more widely in flatter areas of the hull and more closely in areas with more of a curvature appears to have been followed. Preparing a strake for installment in the hull required much adzing of the plank's edges, as well as propping, shifting, clamping, and, in some cases, soaking in salt water and charring to increase the plank's curvature. In the case of the lower strakes, this would have been an extremely time-consuming and strenuous process, particularly since some of the longer strakes were twisted in such a way that they were nearly parallel with the inner face of the keel amidships, but were twisted using char-bending techniques to a vertical- or near-vertical orientation for fastening to the ship's endposts.[388] The score marks made on the inner faces of the planks at numerous coak positions were made when a new plank was bent and shaped in the desired position in

[388] According to Villiers, one Kuwaiti shipwright in the late 1930s considered adding three strakes a day to a hull as an example of overly hasty modern habits, and states that in earlier years adding one strake a day was considered normal (Villiers 2006, 352). This shipwright was building shell-first, but without edge fasteners, which would have made the alignment of planks even more difficult, although these shipwrights did not need to spend time creating edge fastener joints. Steffy (1985a, 101) states in reference to the early Hellenistic Kyrenia ship that "the two resources which the ancient shipwright seems to have had in abundance were the same two which are so restrictive in modern shipbuilding—time and materials. Mortise cutters must have been faster at making joints than we realize, but this entire hull is an example of labor intensity."

the hull; then, the builders removed the plank, drilled holes for coaks in the edges of each of the two planks at the score mark locations, inserted coaks into the coak holes, and drove the new home with mallets.[389] Although most of the caulking appears to have been applied to the plank seams during construction, some caulking was driven later as repairs, based on caulking iron damage to some areas of the keel and to some coaks, caulking around repair planks, and caulking in damaged or rotten areas of the hull. Caulking along the plank seams in the upper hull was probably also driven rather than laid during construction. The port and starboard strakes were intended to be as symmetrical as possible in the bottom of the hull, based on the shapes of the first four strakes on either side of the keel and the roughly symmetrical placement of plank scarfs amidships between FL 20-27. However, this symmetry in hull elements was not perfectly maintained on the port side on strakes SS 4 and SS 5, probably due to a shortage of available planks of sufficient length.

The assembly of the lower hull would have been the most time-consuming and difficult stage in the construction process, and one that relied most on the shipwright's experience. Unlike skeleton-based construction, where the ship is conceived as a series of cross sections based on the frames, a shell-based shipbuilder pays attention primarily to the longitudinal shape of the hull, which is carefully formed over the course of laying

[389] A scoring tool or chalk is used to mark coak and scarf positions during the construction of *pajala prahus* in South Sulawesi in modern times; see Horridge 1979, 14, 16, Fig. 13d. Scoring was used in ancient Mediterranean shipbuilding to mark positions for mortise and tenon joints on the Kyrenia ship; other score marks could have been obliterated by later trimming (Steffy 1985a, 90). A single score mark was found at the position of a dowel or coak on a plank of the Bozburun shipwreck, an indication that the same method was used to mark coak joint locations on that ship as well (Harpster 2005b, 91).

the hull planks.[390] The long, tapered ends of hull planks just before the turn of the bilge (e.g., PS 5, 5A, 4-4, 3-2, SS 3-2 and 4-2, etc.), as well as the tapered edges of some stealer and dropstrake pieces (SS 5-1, PS 11-1, etc.), are the result of the trimming of planks after their installment in the hull. Although the tapered tips of these planks are usually fastened to the hull planking with coaks, they are too thin and fragile to have been attached to the hull in that form; they must have been trimmed to the desired width after they were installed.

The bottom of the hull was nearly flat, with a sharp turn of the bilge occurring between strakes 5 and 8. Regularly-spaced coaks were also used as edge fasteners at the turn of the bilge, but there were some slight changes in the assembly in this area. Strakes 6 through 8 were generally narrower than the previous strakes, probably so that they could be bent and twisted more easily to match the plank edges of the previous strake. Coak holes were drilled through most or all of the widths of these planks at frequent intervals, a construction feature which resulted in many weak points and breaks at coak holes during the excavation. Some coak holes appear to have been drilled at angles on these plank seams, so that the ends of the coaks and coak holes were exposed on the outer faces of the hull planks. In most areas, the planks seem to have simply been bent or twisted until the coaks lined up in their holes and the planks could be hammered together. This resulted in coaks which were bent at the seams, but which nonetheless did

[390] Steffy 1995, 418-19.

not break until the dismantling of the hull during excavation.[391] The edges of some planks at the turn of the bilge, such as the forward ends of the first two strakes on either side of the hull and the outboard edges of SS 5-2 and PS 5, were beveled (usually to a width of 0.3-0.6 cm, increasing to 1.1-1.3 cm in a few locations) to help provide a tight seam in this area.

Beyond strake 8, the hull was assembled using the same methods up to strake 12, with an increase in irregularly-shaped stealer and dropstrake pieces due to the curvature of the hull, particularly between strakes 10 and 12. Many of these narrow coak-fastened planks, such as PS 11-1 and PS 12A, must have been trimmed after their installment in order to provide a smooth sheer before the installation of the first wale, PS 13.

The installation of the first wales involved very different methods than those used to construct the lower hull. Wale PS 13 was connected exclusively to frames; no coaks were used to fasten it to the previous strake. Notches on the upper edge of PS 11 and PS 12 correspond to the locations of the 'long arms' of 13 floor timbers between FL 12 and FL 36. The notches appear to have been produced when the upper edges of the planks were trimmed by adzing or chiseling to ensure a tight seam before the installation of wale PS 13; the wood adjacent to these frames could not be removed with a plane once the floors were installed, and needed to be cut out with an adze or chisel and later

[391] Similar features were found with coaks at the turn of the bilge on the tenth-century shipwreck YK 5.

caulked over.[392] Similar notches on plank edges had been found at the locations of frames on YK 4 in 2007-2008 (see Chapter III). The presence of notches on strakes PS 11 and PS 12 at all of these floor positions (and not at the futtock positions between them) seems to indicate that all of the floors in the main body of the ship were installed in the hull before the wale or the futtocks. This was probably due to the difficulty in bending and installing the wale timbers in place without a pre-erected group of frames to which the wales could be fastened. Tool marks and evidence of char-bending on the inner face of wale PS 13 indicate that the process of installing the wales was time- and labor-intensive, involving the shaping of the wale to fit flush with the strake below it and then bending and fastening it to the floor timbers. This procedure must have required several men, clamps, and props to accomplish. The futtocks must have been installed shortly after wale PS 13 was added to the hull, since the floor timbers extend only to PS 14 or, in a few cases, to strake PS 15.

The floor timbers were shaped first by longitudinally sawing logs with protruding limbs, which in some cases may have been used to produce pairs of adjacent floor timbers in the ship. The flat, sawn faces on the floors show that they were usually sawn from two different directions, with saw marks crossing in the keel/garboard area or just before the turn of the bilge. After sawing, the timbers were dubbed with adzes on the remaining three faces, which included beveling the inner face edges of the timbers. The curvature

[392] The spacing of the notches and floor locations is somewhat irregular (they range from 41.8-56.2 cm apart, with an average spacing of 46.9 cm), an indication that the notches were not positioned based on measurements before the installation of the floors.

of the floor timbers' outer faces in particular required careful shaping to match the hull planking; in some cases, additional adze dubbing of the inner surfaces of the keel and planking was necessary to provide a tight fit between the floor and the inner face of the planking. The limber holes on the floors were probably cut early in this process, after the frame had been roughly shaped and its position in the hull was chosen. The starboard limber holes on the floors are generally lined up very closely with the starboard edge of the keel's inner face. The port side limber holes were frequently out of alignment, and examples on seven floor timbers appear to have been very roughly expanded using a gouge or drill in order to fit them flush against the keel and the hull planking. Score marks on the inner faces of hull planks delineate the locations of the edges of floor timbers in some locations; it is likely that others existed but were cut away during construction or worn away during the life of the ship or after the ship sank.[393] Once a floor timber was given the required shape, it was fastened to the hull with treenails and, in some cases, iron nails.

An area of about a meter in width between FL 25 and FL 30 appears to have been selected as the midship area, around the central transverse hole in Keel 2, the main keel timber. The four floor timbers in this section are all about 1.60-1.70 m long before the upward curvature of their ends at the turn of the bilge, and are all approximately the

[393] Score marks at the edges of frame locations are also frequently found on Roman and Byzantine shipwrecks; similar marks were observed on the planking of YK 1, 2, 4, 5, 11, 23, and 24, studied by INA, as well as the first-century B.C.E. Chretienne A wreck (Dumas 1964, 159; see also Basch 1972, 23), the fourth- and seventh-century Yassıada ships (van Doorninck 1976, 125, Fig. 10; van Doorninck 1982, 59; Steffy 1982a, 71, 73-74), and the fifth-seventh century C.E. Dor D shipwreck (Kahanov and Royal 2001, 260), and YK 12 (Özsait-Kocabaş 2012, 117).

same length. The broadest floors are FL 27, FL 28, FL 29, and FL 30; since the long arms of FL 27 and 28 seem to flare out slightly more than neighboring floors, they are perhaps the best candidates for 'midship frames' in the hull.[394] It is unclear whether these frames were deliberately cut to specific lengths or based on geometrically-determined proportions, as is the case on later skeleton-based hulls. However, the variation in the positions of limber holes on the floors, as well as several other factors, suggest that the use of anything other than a very simple set of proportions is very unlikely (the limber hole locations are often measured in skeleton-building). The arms of the timbers themselves amidships are asymmetrical, reflecting an irregularity in the hull as it was built; in particular, the angles of the port and starboard arms on many of the floors are noticeably different (see Chapter III).

3) The Upper Hull

Once the waterline wales were in place, the upper part of the ship's hull was built using skeleton-first methods. At least two through-beams, which were fastened to PS 13 with treenails between frames FR 29-30, 31-32, (as well as the possible through-beam locations at FR 36-7 and 10-11), were probably installed after the waterline wales were in place. This interpretation is supported by the discovery of a score mark in the upper face of wale PS 13 at the location of the through-beam at FR 31-32. The through-beams on wale PS 13 were positioned approximately 67 cm apart. The two through-beam holes

[394] FL 29 may have had a similar shape, but the 'long arm' end of the floor was broken at the turn of the bilge. If the 'tow hole' in Keel 2 between FL 28 and FL 29 does in fact mark the midship area, then these two frames, along with their associated futtocks could be considered the midship frames.

are roughly aligned with a pair of small mortises cut in floor timbers FL 29 and 32, over the keel (**Figure 4.1**). These were probably cut for receiving the lower ends of stanchions, each of which would have been fastened to the through-beam above it as additional supports, as well as possibly supporting bulkhead panels in the case of F 29.[395] A third set of mortises were found approximately 1.95 m further aft in the inner face of floor timber FL 37, where an additional through-beam was probably located; this though-beam would have accommodated another bulkhead, based on the presence of the grooved futtock F 37 at this position. Unfortunately, the hull planking did not survive in this area above the level of the wale, but a through-beam has been added in this location in the reconstruction. The lack of holes for bulkhead fasteners in the grooved futtocks F 29 and F 37 seem to indicate that they were removable. The pairing of these grooved futtocks with mortises in floor timbers suggests that the stanchions may have been used to support the bulkhead planking as well.

[395] Grooved futtocks or transverse timbers such as the ones found on YK 14 are common on the Yenikapı shipwrecks. The best preserved of these were found on the contemporaneous ship YK 12, which had three grooved futtocks preserved, located three frame stations apart. Some of the contents of the partitioned area included a ceramic brazier, a casserole dish, two amphoras differing from those of the cargo, and a basket of cherries (Özsait-Kocabaş and Kocabaş 2008, 114-17, 122-23). The partitioned area was not covered with ceiling planking (unlike the rest of the hull), and was positioned closer to the stern of the vessel (which can be ascertained based on the locations of mortises in the mast step); a stanchion further aft of the compartment may have supported a deck beam (Özsait-Kocabaş and Kocabaş 2008, 122). Other grooved futtocks were found on YK 3, dating to the tenth or eleventh century, and the early seventh-century YK 11, which had a transverse grooved timber fastened on top of the ceiling and stringers, similar to a timber on the eighth-century YK 29 ship (Özsait-Kocabaş and Kocabaş 2008, 152-54; 2012, 110, Fig. 15.9).

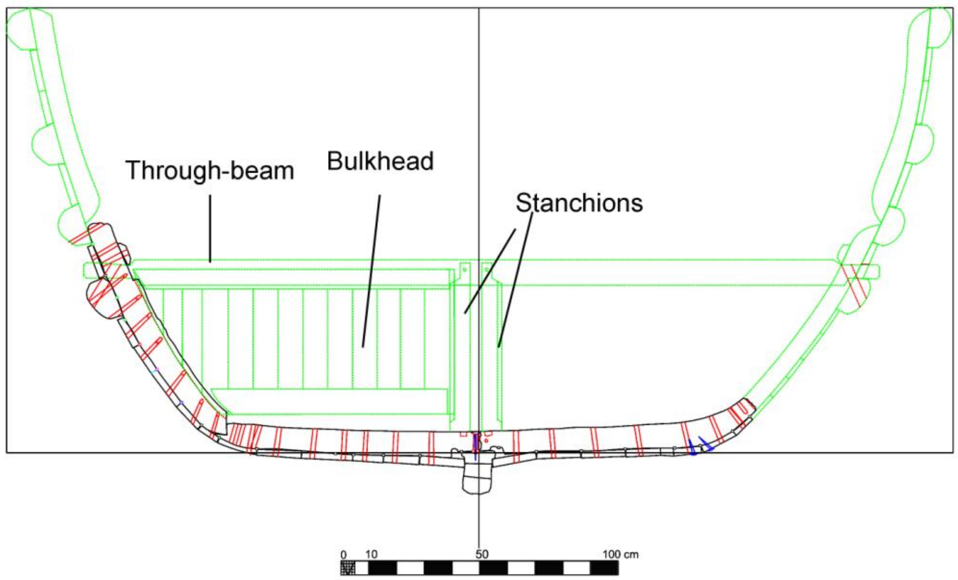

Figure 4.1: Reconstructed cross section of YK 14's hull amidships, at FL and F 29. Timbers shown in black represent surviving hull elements, while timbers shown in green are reconstructed sections. A through-beam supported by a pair (?) of stanchions as well as removable bulkheads (reconstructed here as two panels, one of which is shown in place) were installed in this area.

No evidence for through-beams, stanchion mortises or bulkheads was found aft of F 29 in the central section of the hull, although additional through-beams may have been installed in the upper section of the hull and supported in some other way. Stanchions were unnecessary towards the ends of the hull, where shorter, and therefore stronger, through-beams were used. Based on the small size of the vessel, it is likely that YK 14 was not fully decked, and probably was provided with partial decks only at the bow and stern of the ship. The central part of the ship's hold was probably kept open for ease of loading and unloading cargo. Contemporaneous Byzantine ship depictions often show merchant vessels without decks, although the evidence can be ambiguous (see Chapter

V). Although no remains of the steering mechanism were found, YK 14 would have been steered from the partial deck at the stern with a pair of quarter rudders similar to those depicted on ships in contemporaneous Byzantine art: stern rudders were not invented until the twelfth century, and were not used in the Mediterranean until much later.[396] The steering apparatus would have been supported by one or more through-beams similar to that found on the stern of the late sixth- or early seventh-century C.E. Point Berteau wreck and those depicted in early medieval art.[397] Another probable location for a through-beam was found at the broken aft end of Wale PS 13, aft the futtock F 11's original position, where part of an angled drilled hole, possibly for securing a through-beam, is preserved.

Mortises cut in the inner faces of floors FL 22 and FL 28 over the keel were probably for seating the mast step, which unfortunately was lost. A mast partner, or transverse through-beam, would have been required to support the mast. The through-beam between F 29 and FL 30 probably served this purpose, although a through-beam higher in the hull could have been used instead. In the Middle Byzantine period, a single-masted lateen rig was the standard ship rig in the Mediterranean for a vessel of the size of YK 14; the reconstruction of the ship's sailing rig will be detailed in Chapter V.[398]

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[396] Zafiropoulou 1998, pp. 37-8, 70, 82, 84; see also Mott 1997, 107-53; Pulak 2007a, 211.
[397] Rieth et al. 2001, 43, 63-5. Since the ship had capsized, substantial remains of the upper works of the Point Berteau ship's hull were preserved. On many Byzantine ships, the quarter rudder attachments are obscured by 'wings' at the stern; see the figures in Chapter V for the evidence for steering arrangements on Middle Byzantine vessels.
[398] Bass et al. 2004, 182-84; see also Makris 2002, 96; Pulak 2007a, 211; Liphschitz and Pulak 2009, 167. Although the Serçe Limanı ship probably had two masts, due in part to its "broad, deep, flat-bottomed"

The futtocks at the ‘short arm’ ends of the floors were probably installed just after the waterline wales were in place. Both the floors and the surviving futtocks on the starboard side of the hull extended up to PS 14, (the highest surviving strake in the hull) or PS 15 (which did not survive), so were sufficient for installing the next two strakes without the use of edge fasteners. Coaks were used above the first wale, however, at scarf ends: the forward diagonal scarf on PS 14-2/2-6) was fastened with coaks both to wale PS 13 and to the next plank in the strake (now lost), PS 14-3, while PS 14-1, PS 14-2/1, and PS 14-2/2-6 were fastened to each other with coaks.[399] The apertures in strake PS 14 for the through-beams between FL 28 and FL 32 were cut into before the strake was installed in the hull. The scarf on the ‘short-arm’ ends of the floors must have been cut first, after which the futtocks were shaped using similar methods to the shaping of the floors and fastened in place with treenails and nails. While the futtocks were usually fastened to the hull planking below the wale with a single treenail per strake, they were more often fastened with two or occasionally three treenails to wale PS 13 and PS 14. At some frame locations, one treenail was drilled into another, perhaps deliberately to lock both in place similar to the method of wedging treenails; without coaks to keep wale PS 13 and PS 14 in place, perhaps such additional measures were necessary. Wedged treenails seem to occur almost exclusively on futtocks or frame ends at or above the waterline of the ship, perhaps for the same reason.

hull (Bass et al. 2004, 182), YK 14’s hull is narrower, and there is evidence for only one mast step location.

[399] The planks of the PS 14-1/PS 14-2 plank scarf were fastened to each other but not to PS 13.

Based on the design of other post-seventh-century ships from Yenikapı, the standard design above the waterline was to install single strakes of planking separated by three or four wales in the hull. This pattern was followed on YK 1, a tenth-century ship which, as originally constructed, had four wales between single strakes of planking with similar dimensions to wale PS 13 on YK 14. For this reason, the now-lost strake PS 15 is reconstructed as a second wale similar in size to wale PS 13 in the reconstruction of the hull, and third and fourth wales are surmised to have been installed as strakes PS/SS 17 and 19, separated by single strakes of planking. Strakes 18 was reconstructed as approximately 25-30 cm wide based on YK 14 UM 12, an unusually wide plank that is likely form the upper part of YK 14's hull, although this space could have been covered by two separate planking strakes.

Above wale PS 15, additional framing was required to support the sides of the hull up to the caprail, even though long 'S' or diagonal scarfs, perhaps fastened with coaks, may have been used throughout the upper section of the hull. Rows of treenail holes between floor and first futtock locations on the starboard side indicate that approximately eleven top timbers were inserted in these areas.[400] These top timbers were usually positioned about 90-120 cm apart, between every fourth or fifth frame, although several are more closely spaced towards the bow. Loose futtock timbers found on the wreck site, including UM 15, 17, and 21, may be surviving remnants of these frames. Although the

[400] Top timber positions in the reconstruction are based on groups of fastener holes in the starboard planking between frames FR 11-12, 15-16, 20-21, 24-25, 29-30, 32-33, 36-37, 39-40, 40-41, 43-44, and 44-45. All of the proposed top timbers are based on multiple treenails or drilled holes in the planking, although several single fastener holes in the planking may have also been frame fasteners, such as a treenail in wale PS 13, between FL 37-38.

original lengths of the top timbers are not known, there are similar timbers in YK 1's hull that are probably similar in design: these include top timbers 1.21 to 1.92 m long ('secondary' futtocks; see Chapter VII), as well as a 60-cm long top timber installed directly above the end of one of the first futtocks. These futtocks, along with several strakes, were added in YK 1's hull during a major overhaul to increase the ship's draft, so they are not original hull features; however, it seems unlikely that the shipwrights who modified YK 1 would have deviated significantly from the framing patterns used in other coak-built ships from the site.

Stringers were added at some point after the completion of the framing. At least two stringers were installed along the waterline, probably just above the through-beams. A large section of one of these, ST-1, has survived; it is important to note that it is very small in cross section (7.3 to 8.4 cm wide, and 2.6 to 3.1 cm thick), so it did not play a significant role in strengthening the hull longitudinally. Other stringers or ceiling planks could have been placed in the hull in the area of the turn of the bilge, based on additional fastener holes found in this area on the inner faces of floors on either side of the hull. However, if this were the case, these timbers were not fastened to the frames at regular intervals and likely contributed little to the structural integrity of the vessel.[401] No evidence for a stemson or sternson similar to those found on the seventh-century vessel

[401] Most of the interior of YK 12, a ninth- or tenth-century ship excavated at Yenikapı with a cargo of amphoras, was laid with ceiling planking (Özsait-Kocabaş and Kocabaş 2008, 115-16). Ceiling planks were not found in most of the later Yenikapı vessels—if they were present, they probably floated away during the sinking--although the spaces between floor timbers in one small roundship, YK 9, were filled with sticks of dunnage (Özsait-Kocabaş and Kocabaş 2008, 125).

YK 11 or early ninth-century YK 23 were found.[402] On both ships, timbers of this type were fastened with a single nail on either end (see Chapter VII). Ceiling planking may have also originally been present inside the hull, but would have been lost during the shipwreck if they were not fastened to the frames. Any ceiling planks present left no trace in the hull, except perhaps for some impressions on the inner faces of the floor timbers preserved and possibly the unexplained fastener holes in the floors' inner faces.

4) Analysis of Construction Features

The large number of edge fasteners used in the construction of the hull up to the first wale, and their absence above it (other than at scarf ends) show that the vessel can be accurately described as a hull with 'mixed-construction' features, combining shell-based and skeleton-first techniques. However, the techniques used in the design and construction of the lower hull, the most difficult section of the ship to build, are predominantly those from ancient Mediterranean 'shell-based' construction, while the skeleton-first aspects of the ship's construction appear to be secondary in terms of the hull's design. The extent to which YK 14 was built using traditional Mediterranean methods as opposed to more recent innovations, including the use of skeleton-first techniques, is one of the most important contributions of this vessel to our knowledge of Byzantine seafaring.

[402] A stemson and sternson were found on YK 11; a similar longitudinal timber, possibly a stemson, was also found on YK 23.

There are a number of archaic features clearly apparent in the ship's hull in addition to the use of regularly-spaced edge fasteners. The cross sections of the rabbeted keel timbers closely resemble those of older vessels from the Yenikapı site, such as YK 11 (seventh century) and YK 23 (late eighth/early ninth century C.E.), as well as the galley YK 4. While a rabbeted keel helps to reinforce the hull longitudinally in a hull built with a 'wine-glass-shaped' cross section like those of the Kyrenia ship and many other Greco-Roman seagoing vessels, the shallow keel rabbet on YK 14's keel, combined with the ship's nearly flat bottom, do not appear to give any added structural advantage.[403] YK 14's hull has a sharp turn of the bilge for most of its length, like other Byzantine ships of the tenth and eleventh centuries, but the keel/garboard edge fastening appears to be weaker than that on YK 5, 24, and other flat-floored roundships built in the later tenth-century onwards that lack rabbeted keels (see Chapter VII). The rabbet was helpful in positioning the garboards during assembly, but the probable repair nails along some sections of the keel/garboard connection, as well as the heavy pitch and caulking, may be evidence that this was a weak point in the hull. The rabbet may have also been useful for creating a gutter beneath the limber holes for bilge water to flow, but otherwise appears to have provided few advantages. This design feature can probably be ascribed to tradition and may be one of the last vestiges of the 'wine-glass-shaped' hull design dating back to the Classical period in the Mediterranean. It is probably no coincidence that this feature was abandoned on many (if not all) of the tenth-century merchant vessels from the Yenikapı site built with coaks, which had flatter bottoms and keels with

[403] Steffy 1985a, 100.

rectangular cross sections; this design probably simplified the task of edge-fastening the garboards to the keel, and probably resulted in stronger coak joints as well.

Another traditional feature of YK 14's construction is the use of long 'S' or diagonal scarfs on the ends of planks, almost always connected to each other with two or three coaks. Some shorter diagonal-scarf ends also appear (aside from hood ends), but most are found on repair planks. Butt scarf ends are a typical feature of skeleton-first construction, although they are not necessarily confined to it; if planking is fastened to strong frames, long, elaborate scarf ends such as S-scarfs are generally not necessary, although they continue to be used on some skeleton-based ships such as the Serçe Limanı ship.[404] The use of these scarfs above the coak-fastened section of the hull was probably retained out of habit or tradition.

One important aspect of the ship's construction is the exact role of the frames, specifically whether any frames installed before the first wale are 'active' rather than 'passive' frames, definitions coined by Lucien Basch to describe the role of frames in shell- and skeleton-built hulls.[405] According to Basch, both shell- and skeleton-first methods of ship construction require transverse framing in the hull as reinforcement; however, only in skeleton-built hulls do the shapes of 'active' frames play a primary role

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[404] For example, butt scarfs or half-laps were used on the Mataria vessel, dated to the fifth century B.C.E., which was built using pegged mortise and tenon joints (Ward 2000, 130-33). For three-planed scarf ends in the Serçe Limanı ship's hull planking, see Bass et al. (2004, 107-8, 162).
[405] Steffy uses the term 'control frame' as an equivalent to Basch's 'active' frames (see Steffy 1982a, 82-3); the terms are used interchangeably in this study.

as a guide in determining the shape of the hull as well as reinforcement to the hull.[406] Basch emphasizes the existence of a large number of “intermediary methods” of construction throughout history, which combine aspects of both shell- and skeleton-construction. YK 14 clearly falls into this category, with its shell-built lower hull and its skeleton-built hull from the waterline to the caprail. A hull like YK 14’s, while built using predominantly shell-first methods, could perhaps be built using several prefabricated ‘control’ or ‘active’ frames added to the hull at an early stage of construction to aid in determining the hull’s shape. McGrail calls such a style of construction ‘frame-oriented’ or ‘frame-based’ rather than ‘frame first,’ since the majority of frames do not have ‘active’ roles in determining the hull’s shape.[407] Another possible ‘skeleton-based’ technique is the use of a temporary mold to determine the shapes of frames, a design method that may have already existed in the late Roman Empire.[408]

J. R. Steffy theorized that the Serçe Limanı ship’s construction sequence involve the pre-fabrication of several designed frames amidships and at the ends of the hull, while the shape of the remaining frames was determined by the run of planking and the use of battens.[409] The possibility that pre-erected frames could have been used in the design of YK 14’s lower hull therefore should be considered. The use of edge fasteners does not

[406] Basch 1972, 16.
[407] McGrail 1997, 78-9.
[408] Steffy believes the use of molds or temporary framing in the design of the seventh-century Yassıada ship to be possible but difficult to prove (Steffy 1982a, 83). Bockius (2009, 85-9) proposes the use of such molds in the Late Roman Mainz vessels based on markings on the keel timbers of these ships and (treenails or plugs) in the hull planking between frames (see also Bockius 2006b, 252-301, Fig. 50-74).
[409] Bass et al. 2004, 154-61.

preclude the use of control or active frames; some hulls with large numbers of edge fasteners such as the fourth- and seventh-century Yassıada ships may have required the installation of frame timbers after several strakes were installed.[410] Perhaps the arrangement on YK 14 could have been as simple as one or two pairs of ‘L’-shaped floors amidships and possibly a pair of ‘tail-frames’ at either end of the ship, which, along with the edge-fastened planking, could have been used to determine the shape of the hull.[411] These are important considerations in light of the fact that skeleton-first construction developed in the Mediterranean in the first millennium C.E., perhaps several centuries before YK 14’s construction, if several of the shipwrecks from Tantura Lagoon on the coast of Israel were built using skeleton-first methods (see Chapter VII).

However, a number of features in YK 14’s hull frames cast doubt on the idea of ‘active’ frames playing any role in the vessel’s construction before the installation of the first wale. Rather, these characteristics are those of a shell-first or mixed construction hull, and include the following:

1) The large numbers of coaks found under frames indicate that the floor timbers were not in place before the hull planking. Coaks were driven into plank seams under virtually all of the floors.[412] It would be extremely difficult, if not

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[410] Steffy 1982a, 72-4.
[411] Basch 1972, 29.
[412] A single possible exception is FL 14, a floor timber which was also nailed to the keel. A coak driven through the Keel/SS 1 plank seam also protruded from the inner face of the keel just under the frame. This could indicate that the coak was driven after the frame was in place; however, it seems more likely that the coak ends protruding from the inner face of the keel were cut off later, or the one next to FL 14 was

impossible, to drill holes and hammer coaks home if they were to be located beneath the positions of pre-erected floors.[413] During the construction of a replica of the Kyrenia ship, Steffy found that mortise-and-tenon joints could not be added to the planking if a frame was within 1.5 cm of the joint.[414] On YK 14, treenails and nails for securing the floors were frequently driven through coaks under frame locations, which indicate that the planking was already in place when the fasteners were driven. Most, if not all, of these fasteners appear to have been driven during the initial construction of the hull rather than as later repairs.[415]

2) The presence of notches in the upper edge of the strake below Wale PS 13 indicates that the floors in the main body of the hull from FL 10 to 34 were in place at this stage of the construction. The absence of similar notches on any plank edge below this level, particularly in stealers or other planks with tapered ends, which were probably trimmed or reshaped after installation in the hull, also clearly indicates that there were no pre-erected floor timbers in the main body of the ship before Wale PS 13 was installed.

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simply forgotten. Van Doorninck (1974, 311) has proposed that one of the half-frames in the seventh-century Yassıada ship could have been a control frame based on the apparent intentional avoidance of mortise and tenon joints in the frame's area. Although floor FL 14 on YK 14 cannot be ruled out as a control frame, I believe it is very unlikely based on the lack of similar evidence of control frames in other locations in the hull, as well as the position of FL 14, which neither close to amidships nor to an end, where a control frame would be most useful.

[413] Basch 1972, 23; see also Casson 1964, 88.

[414] Steffy 1982a, 71.

[415] Steffy (1982a, 71) notes this as another indication of shell-first construction on the seventh-century Yassıada ship.

3) Only 20 or 21 of the approximately 50-52 floor timbers or locations for floor timbers in the surviving portion of the hull were definitely nailed to the keel (see Chapter VII, Table 3.5). In skeleton-first ships, typically most or all floor timbers are solidly fastened to the keel, since they must be freestanding to support battens, wales, and hull planking; this at least would be necessary for frames in key areas such as amidships and near the ends of the hull. Frames that were not fastened to the keel are unlikely to be control frames in an early stage of construction.

4) The short arms of the floors were scarfed to fit the lower ends of the futtocks, but they were not fastened to each other in a way that they could freely stand and provide a symmetrical 'skeleton' for securing battens and planking. The floor-futtock connections on the frames of the Serçe Limanı shipwreck as reconstructed by Steffy are relatively simple examples of the types of scarf ends that could be effective for this purpose.[416] Although pairs of freestanding 'L'-shaped floors without futtocks could conceivably serve the same purpose, this would be much less practical since the long arms of each floor are not adjacent to each other, and fastening battens to asymmetrical frames in different locations in the hull would make the battens far less useful as guides for a symmetrical hull shape. Moreover, the relative flimsiness and crooked or undulating shapes of many of the long arms of the floors make such a use highly unlikely. Such light,

[416] Steffy 1994, 89, Fig. 4-14; see also Bass et al. 2004, 95, Fig. 8-9.

irregular framing is a characteristic of ‘passive’ framing in shell-built hulls rather than active frames for skeleton-first construction, in which robust and carefully shaped frames are necessary.[417]

5) The limber holes, which were necessarily cut before fastening the floor timbers to the keel, were frequently widened on one side by several centimeters with a chisel. This was probably because the space cut for the keel on the outer face of the floor did not line up exactly in the position that was desired. The most likely explanation for this feature is that the floors were being shaped to fit flush with previously assembled planking, which would have been the case only in shell-based shipbuilding. In skeleton-first building, particular rules governed the shape of the floors; these necessarily include a centerline location at the keel so that the floors are symmetrical.[418] If this were the case on YK 14’s frames, the limber holes would be evenly spaced on the floors and should not show evidence of being widened later to accommodate the rabbeted keel. Instead, the shipwright appears to have had only a rough idea of the relation between the limber hole locations and the centerline of the ship, and shaped floor timbers to accommodate pre-installed runs of planking.

[417] Basch 1972, 30; see also Steffy 1982a, 82. Steffy (Bass et al. 2004, 159) notes that many of the frames in the Serçe Limanı hull were similarly irregular or “otherwise unsuited for predetermination” or were accompanied by evidence of installment after the bottom planking, such as nail head impressions on the inner faces of the hull planking below frame positions; these probably originate from the use of temporary props or cleats during construction.
[418] See, for example, Bass et al. 2004, 155-56; Rieth 1988.

6) Some features of the planking could have been produced only if the planking was assembled before the frames, such as adzed depressions cut at frame locations and score marks at frame edges. Floor timbers could not have been erected before the frames in areas of the planking where these features are present. Such features are common throughout the hull up to wale PS 13.

7) There is a lack of a clear midship frame, although the widest section of the hull is between FL 25 and 30, and the best candidates for a pair of midship frames are FL 27, 28, 29, and 30. Although the floors in this area have a nearly identical ‘flat’ section of 1.65-1.70 m before the turn of the bilge, they also exhibit an asymmetrical curvature at either end—the starboard side of the frames before the turn of the bilge is slightly higher than the port side—which is not a characteristic of pre-designed floor timbers.

8) The large variations in width over the lengths of many of the planks is another feature of shell-first building, in which plank shapes, in the absence of support from framing, must be altered to minimize resistance around curved sections of the hull.[419] The evidence of hull planks that were char-bent far out of their original shapes is also probable evidence of installation without the benefit of permanent framing; the ends of the first three strakes in the stern of the vessel are good examples of such bending and twisting of the hull planks.

[419] Steffy 1982a, 71.

Some evidence for the use of specific measurements or proportions seems to be present in the hull—for example in the lengths of the keel timbers and the room and space of the floor timbers—but the possible units of length used do not appear to be specific enough or demonstrate sufficient consistency in their use to indicate skeleton-first construction. These features show that it is highly unlikely that any of the frames played an 'active' role in determining the hull shape of YK 14 below Strake 13, the waterline wale. The use of temporary molds in construction cannot be ruled out, although the relatively simple hull shape of the vessel would probably not have required any.[420] Mediterranean precedents for the proposed construction sequence can be found in other well-documented Late Roman and Byzantine shipwrecks that were also shell-built to beyond the turn of the bilge or to the waterline.[421] There are also many historically- and ethnographically-documented hull types built with coak-fastened hull planking that do not require extensive framing during construction, a strong indication that this is an effective method for building vessels with certain characteristics.[422] The sharp turn of the bilge may be inconvenient for a shell-built hull, but the use of coaks, which can be bent

[420] Basch 1972, 34-9; Steffy 1982a, 83.
[421] Steffy 1982a, 72-6, 82-3; van Doorninck 1976, 130-31.
[422] The origin of shell-first construction using coaks is unclear, but regularly-spaced coaks or dowels were used as edge-fasteners in the hull planking of Archaic-period laced-construction vessels (see Chapter VII). Two coak joints were also discovered in plank edges on the second-century C.E. Grado shipwreck, an indication that coak joints were at least occasionally used by Roman shipwrights (Harpster 2005b, 91-2). A number of shell-based vessel types in different construction traditions have built using regularly-spaced coaks, including traditional French and Pakistani riverboats, medieval shipwrecks in Southeast Asia, and vessels built in South Sulawesi and South Vietnam into modern times, and *pereme kütüğü* from the Black Sea (Horridge 1979, 14-7; see also Basch 1972, 31-4; Greenhill and Morrisson, 1995, 54; Rieth 1998, 93-6; Damianidis 1999; Flecker 2007, 75-6, 80-1). Similar variants of edge fastening also existed into modern times, such as the driving of iron nails into recesses cut into the planking, which is practiced in traditional boatbuilding in Egypt and Sudan (Hornell 1946, 193-94, Fig. 29). These construction methods in most cases appear to have been independently invented in at least several regions of the world, and most of these vessel types (e.g., those from Asia) must not be related to the Byzantine tradition of coak construction.

or driven at slight angles, as well as the relative narrowness of the planks likely compensate for this difficulty.

Evidence from the ship's hull itself, as well as comparison to other vessels known from archaeological, ethnographic, and historical sources, attests to the practicality of the mixed-construction method used in the construction of YK 14. The most challenging sections of the hull to design and build, the hull's bottom and turn of the bilge up to the waterline, were built planking-first, perhaps with a few additional temporary cleats added in difficult areas such as the keel/garboard connections at either end of the hull. In 1930, Anders Mattson, a Swedish master shipwright, described the construction of a *galeas*—a vessel built as a shell-first clinker construction to the waterline, and carvel-built over pre-erected frames from the waterline to the caprail—to an ethnographer from the Gothenburg Museum:

> When you build clinker, the ship takes shape under your very hands; if it doesn't turn out so well, you can fix it as you want it. Once you get over the bilge the thing is practically done. Then you can put in the floors and fit the futtocks and top-timbers; they can only go in one way. Then you can plank the rest carvel-fashion and you can build with heavier planking, because you have the frames to give leverage to get the bend on such heavy timber…[423]

[423] Hasslöf 1963, 166.

Steffy "would expect a similar statement from the builder of the Yassıada seventh-century ship, because that was exactly his solution"; a similar statement could be made about the builder of YK 14 as well.[424]

Coaks must have provided significant advantages, based on the large number used in the ship's hull and in spite of the significant investment of time and labor that they represent. The edge fastening holes for coaks needed to be lined up carefully, as shown by the score marks at coak positions; the correct positioning of these edge fasteners must have been more difficult than aligning unpegged mortise and tenon joints.[425] As with any style of shell-first construction using edge-fastened planking, coak construction allows great control over the hull form during the process of construction, but coaks joints could also be made with less labor than pegged mortise-and-tenon joints, and without the need for the more elaborate design methods used in frame-based ship construction. Their relative simplicity and contribution to hull strength are almost certainly two more factors encouraging the development and use of coaks as planking edge fasteners. Like mortise-and-tenon joints coak joints would have also been advantageous for use with timber of mediocre quality; relatively short, irregular planks can be rigidly fastened to the hull without the use of frames.

[424] Steffy 1991, 8.
[425] van Doorninck 1982, 55-6. Coates (2001, 157) mentions the practice of draw-boring, or "deliberately misaligning the holes for tenon pegs so that when a conical peg is driven through, it deforms and draws the tenon more tightly into the mortise." This could have been done deliberately with at least some coak holes on YK 14, and may have also contributed to the distortion seen on many of the coaks.

Coates notes that dowels used as edge fasteners in laced vessel construction make a significant contribution to resisting shear forces, thus decreasing leakage and hogging of the hull.[426] In YK 14, there are far more edge fastenings used than are strictly necessary for aligning the planking and supporting the hull during construction, a design feature reminiscent of earlier pegged mortise and tenon joinery, which had a clear structural use in Greek and Roman ships as “miniature inside frames.”[427] J. R. Steffy believes that closely-spaced mortise-and-tenon joints, particularly when combined with a ‘wine-glass’-shaped cross-section for the hull, added such a degree of longitudinal as well as lateral strength to Greco-Roman ships that other longitudinal supports such as keelsons, stringers, or permanent ceiling were not always necessary.[428]

If the large numbers of regularly-spaced coaks in YK 14’s hull were intended to provide longitudinal strength, their presence could also account for the lack of significant longitudinal timbers in the lower hull as well. There is no sign of a keelson on the vessel, only notches for positioning a mast step over the keel amidships. Conceivably an elongated mast step could serve as a sort of keelson, but there is no indication that it was ever fastened to the floor timbers. The lack of robust stringers in the lower hull eliminates another possible method for longitudinal support of the hull. Although longitudinal strength in the YK 14’s hull could have been provided in other ways, such as the installment of strong wales or other timbers at deck level, the builders probably

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[426] Coates 2001, 154, 156-57.
[427] Steffy 1995, 421.
[428] Steffy 1995, 422.

relied on coaks to provide much of the longitudinal strength of the ship, at a minimal cost in comparison to the use of larger, longitudinal hull timbers.

The use of coaks as edge fasteners may have had considerable advantages not provided by other types of planking edge fasteners, such as unpegged mortise-and-tenon joints. The mortise-and-tenon joints used on vessels such as YK 11 and the seventh-century Yassıada ship would have been fairly loose; the mortises are significantly wider than the tenons, allowing some flexibility in aligning planks.[429] This feature was advantageous since the mortises did not have to match precisely, and would have kept the planks from springing away from the hull during construction. Thinner hull planking could also be used when mortise-and-tenon joints were made smaller and ceased to have an important function in strengthening the hull; such planks would be easier to bend and shape during construction, and were also a more efficient use of material.[430] However, these loose tenons were of a much smaller size than the pegged tenons used in earlier ships, and do not appear to be intended to provide much structural strength to the hull.[431] Coak construction may have provided more rigidity to the hull than unpegged mortise-and-tenon joints, without the loss of other economical hull characteristics such as the use of relatively thin hull planking.

[429] van Doorninck 1982, 55-6; Steffy 1982a, 73, 84.
[430] The hull planking of the seventh-century Yassıada ship was about 3.5 cm thick, with garboards 4.2 cm thick (van Doorninck 1982, 58-9), while YK 11's hull planking was generally 2-3 cm thick (R. Ingram, personal communication). This contrasts with the planking of Greco-Roman ships built with classic pegged mortise-and-tenon joints; many (but not all) of these ships had hull planking of 4-6 cm thickness or even thicker; some larger Roman hulls were built with two layers of planking each fastened with mortise and tenon joints (Steffy 1994, 62-72).
[431] van Doorninck 1982, 55-6; see also Steffy 1995, 420-23.

Coak construction may have provided some additional rigidity that a hull fastened with treenails and unpegged mortise-and-tenon joints would not possess. It probably cost less in materials and skilled labor than was necessary for a hull built using the more traditional mortise and tenon joints as well, particularly if iron fasteners were considered an integral component of this type of construction. Coaks can be produced from branches or twigs, which would be readily available. Drilled coak holes would be easier to make and likely took less skill than the cutting of mortises, and may have had less of a risk of splitting the relatively thin planks. Coak construction, therefore, may have been an acceptable substitute for earlier methods of construction even if there was some decrease in quality of the resulting hull. While the mixed-construction methods used to build YK 14 were still somewhat labor-intensive, particularly in comparison to later forms of skeleton-first construction, in some respects they were an improvement over earlier shell-first and mixed-construction methods which employed mortise-and-tenon joints as planking fasteners. The large number of ninth-to early eleventh-century shipwrecks from Yenikapı built with coaks attests to the usefulness of the method, at least for constructing vessels with light scantling. The lack of mortise and tenon-built hulls from the site after the seventh century seems to indicate that this construction method had probably been abandoned long before the tenth century.[432]

Steffy also notes that shorter, lighter iron nails were used on the seventh-century Yassıada ship than in earlier Mediterranean ships; the planking was held in place during

[432] Based on the planks recycled from other ships, which were used as repair components in YK 14's hull, the salvaged vessels were all coak-built ships built using methods identical to those of YK 14.

construction with mortise and tenon joints, and nails were driven at different angles to increase their holding strength. He characterizes this as "yet another economy measure on the part of the builder. Since the joints were already there, he could use a lighter nailing pattern without fear of individual strakes pulling away under stress. By driving adjacent nails at different angles, as he did, additional holding power was achieved.[433]" The combined use of smaller iron nails as frame fastenings on vessels with unpegged mortise and tenon joints could have also been a way to compensate for the looseness and consequent loss of strength in these edge joints. Treenails were preferred by many early twentieth-century wooden shipbuilders because they "work with the ship, and therefore do not present as unyielding a resistance as a steel fastening;"[434] because more flexible treenails 'work' more with the ship, they therefore leak less. In the partially shell-built, lightly-framed hull of the seventh-century Yassıada ship, perhaps the relative rigidity provided by short iron nails (although less than that provided by longer clenched copper nails used in earlier ship construction) was desirable due to the relative weakness of the ship's edge fasteners, while on YK 14 any loss of rigidity due to the predominant use of treenails as frame fasteners may have been compensated for by the use of regularly-spaced coaks as planking edge fasteners.

The combination of treenails and coaks in YK 14's hull may have had other advantages as well. In post-medieval European shipbuilding, treenails were sometimes preferred over iron nails because of the effects of 'iron sickness,' or the corrosion of iron fasteners

[433] Steffy 1982a, 82.
[434] McCarthy 2005, 64; see also Estep 1928, 13, in Bruzelius 1990.

in salt water, which could lead to severe leakage and weakening of the hull.[435] The high tannic acid level in oak wood could also exacerbate this corrosion.[436] For these reasons, many Iberian shipwrights in the sixteenth century preferred to use treenails as fasteners for the parts of the ship below the waterline, a preference sometimes reflected in many later shipbuilding treatises as well.[437] Similar concerns may have influenced the Byzantine shipwrights who constructed YK 14 and many of the other oak-built Yenikapı ships to use treenails as the primary hull fasteners and avoid such corrosion problems.[438] Treenails are also inexpensive and relatively simple to manufacture in comparison to iron fasteners, and suitable material would have been left over from the initial felling of the timber for the hull. The adoption of regularly-spaced coaks, such as those found on YK 14, rather than somewhat loose, un-pegged mortise-and-tenon joints may have been an alternate method for producing a light but reasonably strong edge-fastened hull built with the cheapest materials possible—locally available oak of fair to mediocre quality—when iron nails became more expensive or less easily obtained.

The intended use of the ship as well as available materials for its construction must have largely determined its construction method. Iron nails and bolts were the primary fasteners used in the hulls of Middle Byzantine-period ships found elsewhere off the coast of Turkey, including the ninth-century Bozburun ship and the early eleventh-

[435] van Doorninck 1982, 55; see also Alston 1972, 110; McCarthy 2005, 64, 109-110.
[436] Smith 1993, 79; see also McCarthy 2005, 64.
[437] McCarthy 2005, 64-5.
[438] For example, the oak-built vessel YK 23's frames and planking were fastened entirely with iron nails, and many of the later Yenikapı ships have large numbers of iron nails in their hulls (see Chapter VII).

century Serçe Limanı ship.[439] Although both ships were of a similar size to YK 14, they were much more heavily built and were likely built as long-distance, open-sea traders. On the other hand, YK 14's light framing and apparent absence of heavy longitudinal stiffening timbers in the lower hull suggest a vessel built for coastal sailing or for inland waters rather than for voyaging on the open sea over long distances. Although it is possible that YK 14 may have been used for long-distance travel, particularly during the fair-weather sailing season, it was probably far more suitable for short coastal trips in the more sheltered waters of the Sea of Marmara and the Bosporus or up local rivers.[440] By the later tenth century, when much of the original Theodosian Harbor had silted up, flat-floored cargo vessels became common at Yenikapı.[441] Since such a design is suitable for use in shallow water and for beaching, these small vessels could have been used in harbors and inlets with minimal harbor facilities.[442]

5) The Bow and Stern of the Vessel

One final point on the construction of the hull is the identification of the bow and stern of the ship. YK 14 has a double-ended hull, the mast step is missing, and those indicators used to determine the bow and stern on other shipwrecks (such as the location of anchors and cargo, and the placement of quarter rudders) are not present. The notches for a mast step in floors FL 22 and FL 28 are roughly amidships, an ideal location for a single mast,

[439] Bass et al. 2004, 106-7; see also Harpster 2005a, 126, 129-31, 172.
[440] Pulak 2007a, 211, 213.
[441] Pulak 2007a, 202-3; Liphschitz and Pulak 2009, 165-66.
[442] Pulak 2007a, 202-3; see also Liphschitz and Pulak 2009, 165. Such use of seagoing vessels seems to have been common, based both on shipwreck finds and from textual references to sea voyages and sea travel from the period (McCormick 2005, 418-22).

raked forward and rigged with a lateen sail. A mast partner, probably in the form of a through-beam, would be necessary for supporting the mast higher in the hull (see Chapter V). The though-beam aperture on the planking between frames FR 29-30 could have served this purpose, although a through-beam higher in the hull would have worked equally well.

Another possible indicator of the ship's orientation is the wear on the transverse holes in the keel, which occurs only to one side on each hole. Kocabaş notes that the wear occurs on the forward ends of the holes. This assertion appears to be based in part on the YK 12 shipwreck, whose keel timbers have two holes similar to those in YK 14; on YK 12, the bow and stern of the ship are known based on the size and position of mortises in the ship's mast step.[443] If this indication is correct, then Keel 3 is the forward-most keel timber on YK 14. Keel 3 exhibits significant wear on the outer face in a localized area between FL 38 and 40, where the flat, aft section of this keel is located. This was very likely caused by repeated dragging or beaching of the vessel on shore, bow-first (although the ship could have been beached in the opposite direction as well).

One final piece of evidence for the bow and stern of the vessel is the entry of the ship, or its hull shape at the bow. The hull around Keel 3 is rounder and fuller, which is more indicative of the bow of a vessel in most construction traditions. However, Steffy's

[443] YK 12's mast step is cut with two mortises: a larger mortise in the center of the mast step for the heel of the mast, and a smaller mortise towards one end for an upright post to which the mast is lashed (see Chapter V for more details of this support structure) (Özsait-Kocabaş and Kocabaş 2008, 114-16; Özsait-Kocabaş 2012, 115).

reconstruction of the seventh-century Yassıada hull includes a very fine entry and a midship frame aft of the center of the vessel.[444] A fine entry is evident on some vessels in Middle and Late Byzantine art as well.[445] In spite of some ambiguities, however, Keel 3's location still seems to be the most likely candidate for the forward end of the hull, based on the hull shape in the bow, the larger dimensions of Keel 3 in comparison to Keel 1, the positions of the transverse holes in the keel timbers, and the evidence of wear on around the holes' edges, and the location of the FL 28-29 through-beam aperture in relation to the mast step position, which is in a logical location for the mast partner.

6) Repairs and the Age of the Ship

YK 14 saw at least a few years of service before it sank, based on several types of evidence for repairs. The hull was clearly affected by some form of fungal rot which caused significant damage to frames and plank seams, which was repaired in many areas with caulking and pitch. Some areas of the hull show significant wear, including parts of the outer face of the keel and the inner faces of the hull planking. Various repair fasteners (and probable repair fasteners) are found in many parts of the hull, particularly in the area at the turn of the bilge; unfortunately, it is impossible to unequivocally identify many of the hull fasteners as either repairs or original hull features. Twelve repair planks and possibly one or two repair frames (FL 44 and F 44) suggest a relatively long career for the ship. These repairs vary in size and in degree of craftsmanship. Some plank edges around the replacement pieces are quite carefully cut, such as the inset area

[444] Steffy 1982a, 85.
[445] Harpster and Coureas 2008, 15; see also Zafiropoulou 1998.

cut for installing the repair piece SS 5-2A, a graving piece at the turn of the bilge on the port side. At other locations, the planking was rather roughly cut away and the resulting gaps were simply filled with large amounts of caulking, as with planks PS 4-3 and SS 6-2A. There appear to be differing degrees of wear to repair planks as well. Some, such as SS-2A, PS 11-2/6, and PS 5A/1-1A, were found to be in excellent condition, while others exhibit significant wear after their installment in the hull. A split down the center of repair plank PS 6-2/2-4, the heavy wear on its outer face, a large plugged hole from dry rot, and a peculiarly-shaped aft scarf which abuts a second repair piece, indicate that this plank had likely been in place for a long period before the ship's sinking, and may have already been an old plank when it was installed in YK 14's hull. Although some of the differences in preservation of the replacement planks are likely due to their age and wear from their previous uses, it is probable that they were installed over the course of several maintenance episodes and that this is reflected to some extent in the condition of the planks.

It is difficult to estimate the length of time that the ship was sailed based on these vague clues, but at least five or ten years of use seems plausible. None of the repairs are major; perhaps the most serious is on the aft section of PS 2, where two short planks, including one with a hood end, were used to replace part of the original hull plank. This contrasts with several other Yenikapı shipwrecks studied by INA, which exhibit evidence of much more extensive repairs to their hulls. The small roundship YK 24 was heavily repaired, with several planks as well as keel timbers replaced in the relatively small area of the hull that survived; many iron nails used to fasten the hull planking to the frames were almost certainly added during the overhaul. The timbers of the ship itself were noticeably more worn than those of YK 14. The situation with YK 1 was similar, with several repair planks, many repair nails, and evidence of a major overhaul of the ship at some point in its career in which several new strakes were added to the hull.[446] The galley YK 4 also had a significant number of frames added to its hull at a later time, estimated as approximately one-tenth of the total number of preserved frames.[447] Extensive repairs are also seen on the seventh-century ship YK 11, which had most of its original planking and about half of its original frames replaced in at least two separate episodes during its career, before its probable abandonment as a derelict in a swampy, refuse-filled area on the western end of the site.[448] The condition of these vessels suggests that YK 14 would also have been used as long as the ship could be kept afloat. In spite of some damage to the hull, the ship's condition is too good to have been abandoned as a derelict, and would have probably been used for many more years if it had not been lost in a storm.

7) Reconstruction of the Ship's Lines and Dimensions

The major dimensions of the hull and a preliminary set of ship's lines are presented below (**Table 4.1; Figure 4.2**). See Appendix A for estimate of hull capacity and tonnage.

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[446] Liphschitz and Pulak 2009, 166-67.
[447] Liphschitz and Pulak 2009, 169.
[448] Ingram and Jones 2010, 13; 2012, 19.

Table 4.1: YK 14 Reconstruction: Principal Dimensions

Category:	Meters:	Byzantine Feet (31.23 cm):
Length, estimated overall:	14.68	47.01
Length on waterline (overall):	12.18	39.00
Length of keel (effective):	6.60	21.13
Breadth, estimated maximum:	3.40	10.89
Breadth, molded:	3.25	10.41
Breadth, molded at waterline:	2.82	9.03
Breadth of floor (Approximate, to turn of bilge):	1.80	5.76
Depth, estimated overall:	1.75	5.60
Depth of hold, reconstructed:	1.60	5.12
Draft at full load:	0.85	2.72
Draft, molded:	0.70	2.24
Keel, sided (average):	0.112	0.36
Keel, molded (average):	0.144	0.46
Frames, sided (average maximum):	0.058	0.19
Frames, molded (average maximum):	0.095	0.30
Room and space (average):	0.229	0.73
Planking, thickness:	0.023	0.07

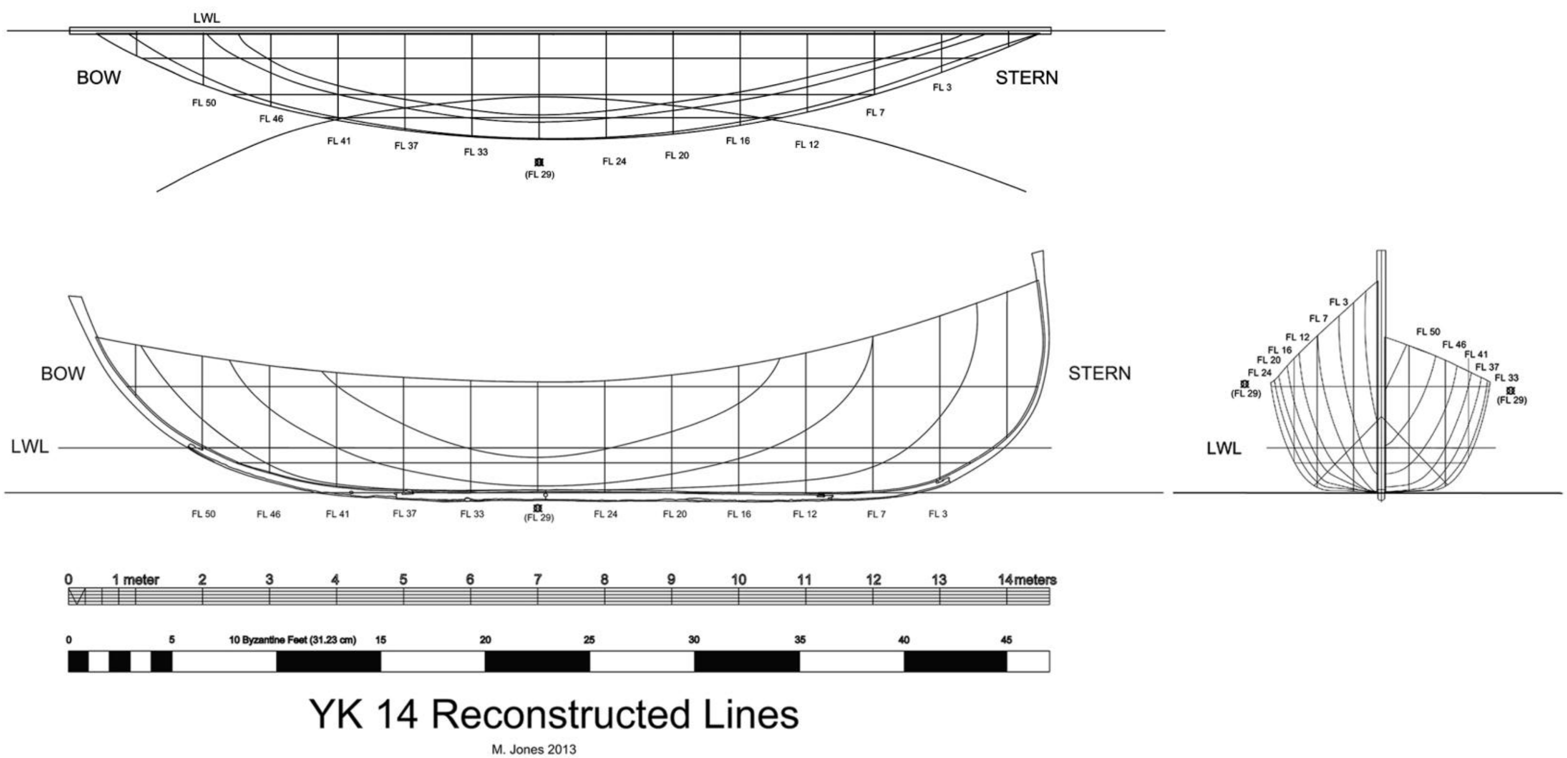

Figure 4.2: Preliminary Ship's Lines.

CHAPTER V

THE SHIP'S RIGGING AND EQUIPMENT

1) Introduction: Primary Sources of Evidence for Byzantine Ship Rigs

The reconstruction of YK 14's sailing rig and equipment relies on three main sources. The first and most important category of evidence are archaeological remains, including the surviving portion of the ship's hull, rigging elements found in YK 14's excavation area, and archaeological evidence from other shipwrecks, both from Yenikapı and other shipwreck sites. The hull remains also provide information on the ship's stability, a major factor in the design and reconstruction of the ship's rig.[449]

Secondly, artistic depictions of ships from the Late Roman and early medieval periods provide vital information on ships' rigs and equipment that has not survived in the archaeological record. Although ship iconography often presents problems of interpretation (particularly when artists omit or confuse details), some depictions provide a wealth of technical details; ships depicted in Byzantine art and graffiti are usually the best evidence for the actual appearance of a vessel of the period under sail. The iconographic evidence can in many cases be interpreted using a third source of information, namely later historical and ethnographic sources detailing the use of similar rigs. Ancient and medieval art shows that the lateen and closely related settee rigs were the dominant ships' rigs in the Middle Byzantine period, sail types that have also been

[449] Steffy 1994, 9-10.

used with relatively few changes in the Mediterranean and Indian Oceans into modern times.[450] For this reason, later accounts of the design and use of the lateen rig are valuable resources for interpreting both the archaeological remains of Byzantine ships and depictions of vessels under sail in Byzantine art. In general, the features of the rig and equipment in this reconstruction are based on the simplest configuration required for the rig to function, unless there is compelling evidence that a more elaborate arrangement was in place.

1) The Lateen and Settee Rigs

Throughout the Middle Byzantine period, the lateen and settee rigs were the primary ship's rigs used in the Mediterranean. The lateen rig is a fore-and-aft rig consisting of a long, single yard, usually made up of at least two spars woolded together, and a triangular sail (**Figure 5.1**).[451]

[450] Campbell 1995; see also Le Baron Bowen 1949; 1953; Bass et al. 2004, 182-84.
[451] Marquardt 1992, 152, 159-60.

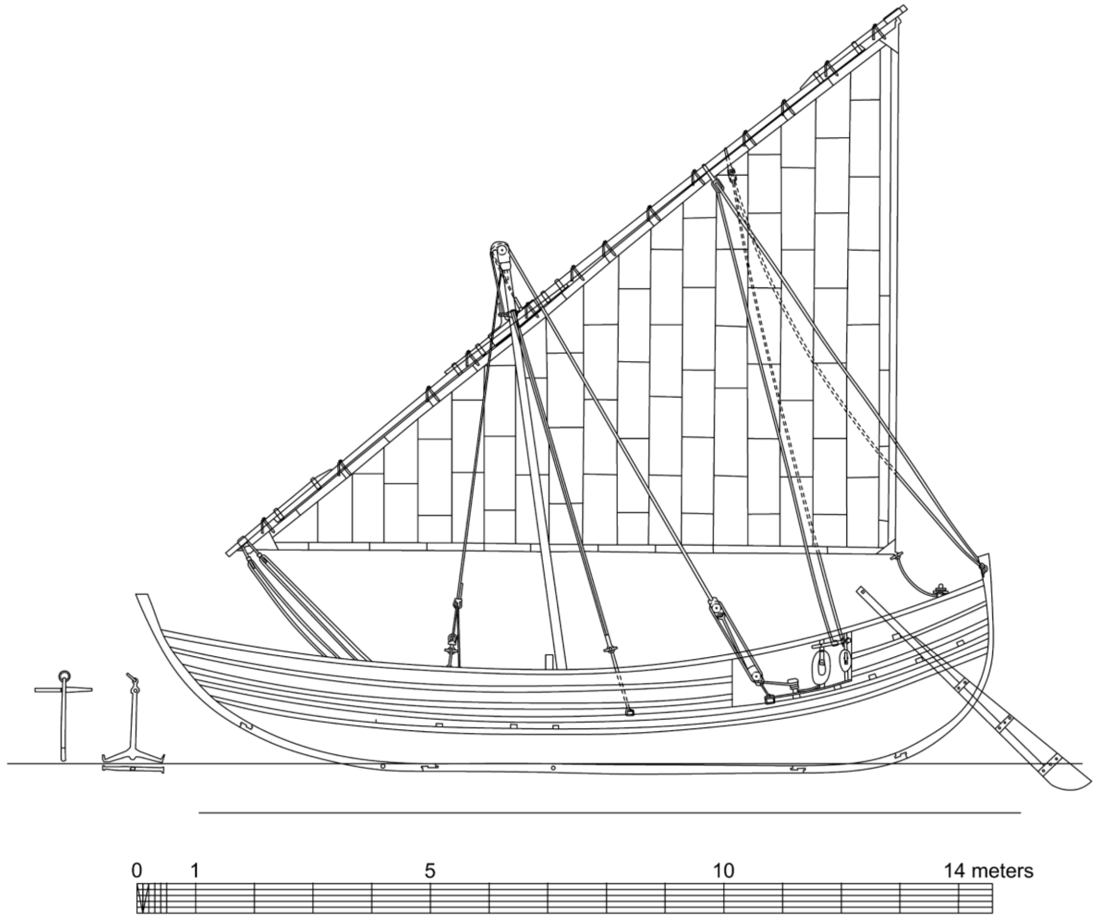

Figure 5.1: Reconstructed rig of YK 14, with the major parts labeled, shown on the reconstructed hull of YK 14.

The settee or 'Arab lateen' rig uses the same rigging elements as a lateen rig, but the sail is quadrilateral rather than triangular, with a short luff on its leading edge.[452] YK 14's rig has been constructed as a lateen rig based on the surviving Byzantine ship depictions closest in date to YK 14. Some scholars believe the settee sail represents an earlier version of the lateen sail, which may have evolved from attempts to use a square sail as a

[452] Whitewright 2012, 2-3; see also Casson 1966, 44-5; 1995, 243-45, Fig. 175-82.

fore and aft sail;[453] regardless of its origin, it was likely in use in the Mediterranean in the ninth and tenth centuries alongside the lateen sail.[454] For the purposes of this chapter, features of the 'lateen rig' will refer to both types unless there is a significant difference in the features of the two rigs.

For a lateen rig, either one or a pair of halyards runs to the mast head. The halyards are used to lift the yard and sail, while a throat tackle is used to secure the yard to the mast once it is in position. The halyards are run through a third double block, either a loose block secured near the top of the mast or a double block built into the mast head. At least two running shrouds are used to secure the mast on the port and starboard sides; these lines are not permanently fastened to a single location, since they must be moved when the ship wears to windward, an operation that involves furling the sail, tilting the yard vertically, and swinging the yard around the forward face of the mast (**Figure 5.2**).[455] Lines attached to blocks fastened at the upper end of the yard are called vangs. Vangs are used to keep the sail and yard in a desired position; they are secured to the upper end of the yard and belayed at deck level.[456] A sheet is the line used fastened to the aft lower corner of the sail, while tacks or clews secure the lower end of the yard in the bow.[457]

[453] Campbell 1995, 2-4, 20-2.
[454] Hourani 1995, 101-5; see also Le Baron Bowen 1949, 89, 91-3; Basch 1997; 2001; Pomey 2006, 329; Whitewright 2012, 7-8, 13-9.
[455] Lateen-rigged ships almost always sail to windward by wearing rather than tacking due to the handling characteristics of the rig (see Harland 2006, 13, 181-8, 191-3 for a detailed description of these maneuvers). Villiers (2006, 49-51) describes one instance of tacking in a lateen-rigged Kuwaiti *boum* off the coast of East Africa in an emergency situation, but emphasizes the risk of the maneuver.
[456] Dimmock (1946, 38) prefers to call these lines braces "because the yard is never hoisted without a sail."
[457] Howarth 1977, 23.

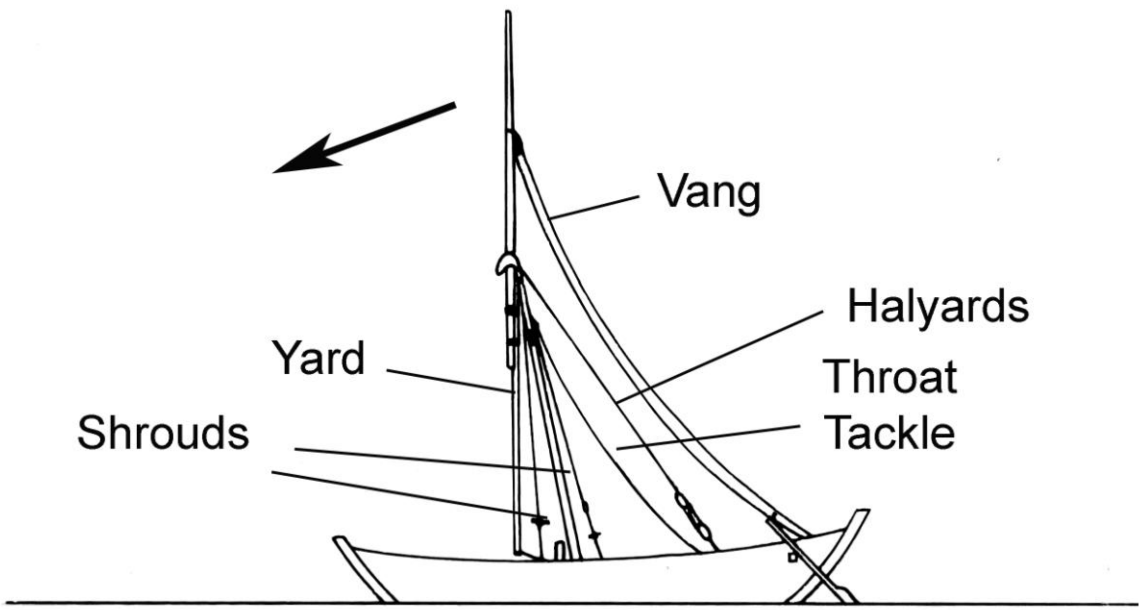

Figure 5.2: Changing tack in a lateen vessel. In order to change direction while sailing to windward, the halyards, vang, and throat tackle or parrel must be loosened, the running shrouds must be transferred from the leeward to the windward side of the ship, and the yard is pulled to a vertical position and maneuvered to the other side of the mast, where the halyards and throat tackle again secure it in place (Adapted from Hawkins 1977, 31, and Pryor 1994, 67).

This is the simplest version of the lateen and settee rigs used in antiquity, and into modern times in the Mediterranean, Persian Gulf, and Indian Ocean.[458] Heavier and more complex rigging tackle were developed for larger lateen-rigged vessels, but were not necessary for small merchant ships such as YK 14.[459] The details of contemporary and ethnographically-documented lateen rigs from the Mediterranean and other areas are

[458] Le Baron Bowen 1949, 111-14, 116-17; see also Dimmock 1946; Lishman 1961, 57.
[459] See, for example, the rigs of much larger twentieth-century dhows (Villiers 1962, 113-14, 120-22; Jewell 1969, 23, 27-8; Howarth 1977, 86-7; al-Hijji 2001, 78-90).

remarkably close to those seen in Late Roman and early medieval art from the Mediterranean.

The lateen or settee sail offers several advantages over the square sail, particularly in the environments of the Mediterranean and western Indian Ocean, where it remained in use until recent times on local craft. In both regions, winds and weather are highly predictable seasonally, and light winds are typical for much of the year.[460] As a fore-and-aft sail, the lateen/settee sail produces less drag than a square sail, and is therefore more effective in light winds; lateen-rigged ships can also sail closer to the wind than a vessel with a square sail.[461] A lateen or settee sail also allows a larger sail to be set than is possible with a square sail used on a mast of the same height.[462] The lateen/settee sail also has several disadvantages, however. Its large sail area is extremely difficult to handle in rough or unpredictable wind conditions, and changing direction while sailing into the wind is a difficult operation. Lateen-rigged vessels wear into the wind rather than tack due to the difficulty of maneuvering the heavy main yard around the mast.[463] Lateen-rigged vessels also require larger crews than square-rigged vessels for hoisting and maneuvering long lateen yards.[464]

[460] Pryor 2000, 1-6, 15-24, 87-9; see also Villiers 1962, 123; 2006, 30, 51, 91, 302; Kreutz 1976, 98; Murray 1987.
[461] Campbell 1995, 2; see also Villiers 2006, 240. Another advantage to the rig is that the sail can be lowered in adverse wind conditions by lowering the yard, a much quicker operation than reefing a square sail (although reef points may have been used on some Byzantine settee sails: see p. 14-5, Figure 5.11). Although this is an advantageous feature for foul weather sailing, this can still be a difficult operation due to the size of the sail (Hourani 1995, 109-110; see also Kreutz 1976, 98; Villiers 2006, 241-42).
[462] Howarth 1977, 86.
[463] Campbell 1995, 13; see also Villiers 2006, 50-1, 241-42.
[464] Campbell 1995, 19.

The performance features of the lateen rig have been cited as a reason for its widespread adoption in the early Byzantine period; faster, more maneuverable lateen-rigged ships, it is believed, were better suited to a period in which piracy and warfare was common.[465] More recently, this has been called into question. John Pryor believes the rounded hulls and small keels of early medieval ships would have offset many of the performance-related advantages of using the lateen sail, while J. R. Steffy notes that the Serçe Limanı hull's shape, while advantageous from the perspective of cargo capacity and simplicity of design, resulted in a hull that was "infinitely more clumsy than the clippers and other fast sailing ships" of later periods.[466] Julian Whitewright proposes that there was little overall difference in performance of lateen vs. square sails on ancient ships based on ancient and medieval records of the duration of voyages.[467] As an alternative explanation for the popularity of the lateen rig in late antiquity and the early Middle Ages, Whitewright proposes that its adoption may have been based on the relative simplicity of its rig, which did not require the standing rigging or elaborate brail line arrangements used in the rigs of the Greco-Roman period.[468] The reason for the lateen rig's popularity may have, therefore, been related to a combination of its suitability for sailing conditions in the Mediterranean and its relative cheapness and simplicity.

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[465] Kreutz 1976, 81-2, 86, 99; see also van Doorninck 1972, 139.

[466] Bass et al. 2004, 169. Steffy's comments could also apply to many of the flat-floored Yenikapı roundships as well.

[467] Pryor 2000, 33-4; see also Whitewright 2011b. Kreutz (1976, 82, 105) notes that "It is unlikely that the comparatively small lateeners of the early Middle Ages presented quite so sharp a contrast to the square-rigged ships which had preceded them. Moreover, when lateen sails did become really huge, as the ships themselves grew bigger in the central Middle Ages, some of the troublesome aspects of this rig became increasingly apparent."

[468] Whitewright 2011a, 100-2; 2012, 14-6.

2) Archaeological Evidence for the Ship's Rig

The Mast Step and Mast Partner

Unfortunately, little direct evidence of YK 14's rig survives from the ship's hull remains; much of the reconstruction relies on indirect evidence such as evidence for the locations of through-beams and stanchions and comparison to other shipwrecks. However, one vital piece of information, the position of the mast step, is known based on the presence of mortises over the keel in two floor timbers, FL 22 and 28, spaced 1.39 m apart. The use of these mortises for accommodating mast steps is confirmed by other ninth- or tenth-century shipwrecks from Yenikapı, which had mast steps were found nailed in place.[469] On YK 14, these mortises occur approximately amidships, a position consistent with a mast step for a single lateen sail.[470] The preserved mast steps from Yenikapı and later examples of mast steps for lateen-rigged vessels usually have two mortises: one for the heel of the mast itself and another for an upright post to support the mast, against which, in some configurations, the mast rests (**Figure 5.3**).[471]

[469] Özsait-Kocabaş and Kocabaş 2008, 124, Fig. 22; 2012a, 111, Fig. 15.11.
[470] Bass et al. 2004, 180.
[471] Basch 1991a, 7.

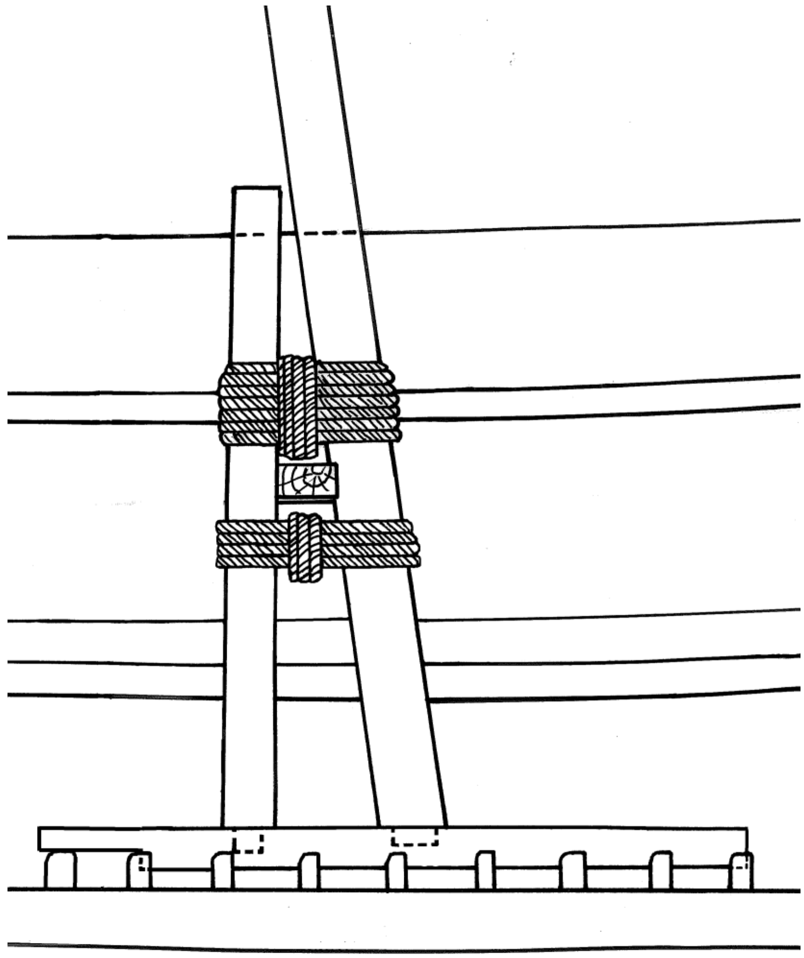

Figure 5.3: Reconstruction of the mast step assembly, which includes a mast step with two mortises: one for the mast heel and one for an upright post, a mast partner, and rope used for lashing the assembly together above the mast partner.

A mast partner would have been required for bracing the mast higher in the hull as well, but no evidence for this feature survived. Additional mortised blocks, called mast-step sisters, were sometimes employed to support transversely-oriented angled supports; a well-preserved assembly of this type was found on the Tantura F shipwreck discovered off the coast of Israel (c. 650-800 C.E.).[472] Although possible supports of this type were

[472] Barkai and Kahanov 2007, 24, 26, Fig. 9.

also found on YK 11, no evidence for mast-step sisters was found on YK 14 or the later Yenikapı roundships documented by INA, so they are not included in the YK 14 reconstruction.

Preserved Rigging Elements

A sheave fragment, three rope fragments, and a possible rigging toggle were found in the immediate area of the shipwreck. None of these artifacts can be definitively identified as parts of YK 14's rigging, but they are fairly typical of rigging elements found on other Byzantine shipwrecks and as isolated finds at Yenikapı site, and are suitable for a ship of YK 14's size. These artifacts, as well as rigging elements from other shipwrecks and published examples found elsewhere at Yenikapı were, therefore, used as guides for the dimensions of blocks, toggles, and rigging lines.

The sheave fragment (YK 14 UM 23) is 3.0 cm long and 2.0 cm thick, and is part of a sheave originally about 5.0-6.0 cm in diameter (**Figures 5.4-5**). The sheave was made from a lathe-turned piece of boxwood (*Buxus sempervirens*), and has a shallow groove cut into its circumference, with two parallel scored lines in the middle. The size and design of the sheave are similar to better preserved examples found across the Yenikapı site, and in the vicinity of YK 1, 4, and 5; several similar examples are 4.5-6.4 cm in diameter and 2-3 cm thick (**Figure 5.6**).[473]

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[473] Çölmekçi 2007, 238; see also Gökçay 2010, 147.

Figure 5.4: Outer face view of UM 23.

Figure 5.5: Profile view of sheave fragment UM 23.

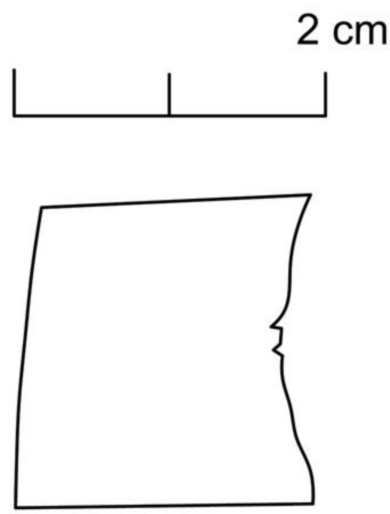

Figure 5.6: UM 23, cross section.

UM 24, a second wood object possibly related to the rig of the ship, was found to the west of the port side of the ship in the same stratigraphic layer during the initial excavation in April 2007. UM 24 is a toggle, 20.9 cm long, with a maximum diameter of 2.9 cm; it has tapered ends and a 3.8 cm wide, 1.3 cm deep notch cut at its center. The object was carved of oriental beech (*Fagus orientalis*) (**Figures 5.7-8**) and has some resemblance to carved toggles used for the running rigging of ships, which are fairly common finds at Yenikapı. However, these are typically made of oak rather than softer beech and are of a more robust design than UM 24 (**Figure 5.9**). UM 24 may, therefore, have had a different function than as a toggle used in a ship's rigging.

Figure 5.7: Beechwood toggle found under the hull of YK 14. Although its dimensions are typical of other toggles found at Yenikapı, the design of this toggle with a notch in the middle is different from that of other rigging toggles found on the site. It is possible that it may be unrelated to rigging.

Figure 5.8: YK 14 UM 24: a view of the notch in the center of the toggle.

Figure 5.9: A typical oak rigging toggle found under the hull of YK 24 (tenth century).

Two rope fragments found in the excavation area, which were approximately 2.3-2.5 cm in diameter, would have fit well in the block from which the UM 23 sheave fragment came, and are of a similar diameter to ropes found on other shipwrecks.[474] The ropes are 3-strand hawser laid ropes with a 'Z' twist.[475] The better preserved example is Fragment #1, an approximately 50 cm-long section found 10-50 cm south of the aft end of the aft keel timber (Keel 1) (**Figures 5.10-11**). Fragment #2 was found between separated strakes SS 6 and 7 in the area of FL 29-31. This rope fragment was more poorly preserved, and the strands were more difficult to distinguish, but it was made from the same material as rope Fragment #1. It was originally about 48 cm long, but partially disintegrated during its excavation; a main portion with a length of about 25 cm survived, and most of the rope fibers were recovered and bagged separately.

Table 5.1: Rope Dimensions

Rope Fragment #, location:	Preserved Length (cm):	Diameter (cm):	Strand Diameter (cm):
Rope Fragment 1:	50 (approximate)	2.4	1.0-1.2
Rope Fragment 2:	48 (approximate)	2.5-2.8 (approx.)	1.3 (approx.)

Both rope fragments appears to be made from tree bast, possibly lime or linden bast (*Tilia* species), rather than from flax or hemp (see Chapter VI).

[474] Rope fragments of diameters from 1.2-4.0 cm were recovered from the Tantura B shipwreck (Charlton 1995, 17)
[475] For the terminology of rope structure, see Sandars 2010, 6-8.

Figure 5.10: Rope fragment #1 after cleaning and sampling.

Figure 5.11: The best preserved section of Rope fragment #2.

3) The Lateen and Settee Rig and Iconographic Evidence for Their Use in the Roman and Early Medieval Mediterranean

Fore-and-aft rigs had been invented in the Mediterranean by the third or second century B.C.E., based on Hellenistic-era depictions of sprit rigs on what appear to be small cargo or fishing vessels.[476] The earliest proposed settee rig is from the tombstone of Alexander of Miletus, dating to the second century C.E.; the sail shape and its fore-and-aft orientation are clearly apparent, although there are no additional details of the rigging shown.[477] Basch suggests that the settee and lateen rigs evolved from canting the yard on square or quadrilateral sails on small craft in the Hellenistic and early Roman period, citing examples of reliefs on tombstones and graffiti; this may have eventually led to their use as fore-and-aft sails, first on small craft, and later, on larger vessels.[478]

Textual references to lateen or lateen-like sails appear by the fifth and sixth centuries C.E. in descriptions of large cargo vessels and warships, at the same time that artistic representations of ships with square sails are disappearing.[479] A detailed depiction of a settee-rigged ship was preserved in a mosaic pavement in the ancient city of Kelenderis (modern Aydıncık), in the province of Içel on the southern coast of Turkey (**Figure**

[476] Casson 1995, 243-45. Many scholars have suggested that the lateen was invented in the Indian Ocean by Arab seafarers based on its modern distribution and widespread appearance in art only in the early medieval period, but Casson, Basch, and others note much earlier Mediterranean precedents for its use (Casson 1966, 45-9; see also Le Baron Bowen 1949, 89-94; Basch 1989; Hourani 1995, 101-5; Basch 1997; 2001; Pomey 2006, 329).
[477] Casson 1995, Fig. 181; see also Whitewright 2009, 102.
[478] Basch 1989, 329-30.
[479] Pryor and Jeffreys 2006, 153-57; see also Procop., *Bell.* 1.13.3; Casson 1952; 1956; 1966, 49-51; 1987; 1995, 245, n. 82.

5.12).[480] The mosaic is dated to the fifth or sixth century C.E.[481] Features shared with other Byzantine ship graffiti of the period include a slightly raked mast with a downward-curving hook-shaped mast head, a long inclined yard, a settee sail, a forestay, upright supports around the mast (a *xylokastron* or tabernacle), protruding bitts near the bow, and a pair of halyards running to the backstay and run through a pair of halyard blocks.[482] A protrusion from the prow with a curved extension similar to that on the mainmast is probably a small foremast for a second sail; Martin states that "the hook shape would have kept the halyard as far forward of the mast as possible, to allow the unfettered movement of the yard necessary for tacking."[483] A second, smaller, undecked, single-masted ship has a similar rig to the main ship in the mosaic.[484] A notable feature on the sails of both vessels is the row of reef points; these are unique in lateen sail depictions from the period, are not a feature of earlier square sails (which were manipulated with brail lines), and are not used on later lateen or settee sails.[485] This feature may represent a transitional type of quadrilateral sail descended from square sails.[486]

[480] Friedman and Zoroğlu 2006, 108.
[481] Friedman and Zoroğlu 2006, 108.
[482] Pomey 2006, 327-28; see also Basch 1991a, 18-20. Friedman and Zoroğlu (2006) describe the Kelenderis rig as a quadrilateral sail, but Pomey (2006) and Roberts (2006) convincingly argue that the rig as a settee rig similar to that shown in the graffiti from Kellia and Corinth.
[483] Pomey 2006, 328; see also Martin 2001, 56. This interpretation is also supported by Pryor (1994, 70-1).; see also n. 565 for an alternative explanation. Similar hook-shaped mast heads (with built-in blocks positioned one above the other) are used on the mastheads of Indonesian *praus*, although these mastheads face aft rather than forward and are used for a boom-footed quadrilateral sails rigged fore and aft, similar to Nile *nuggars* (Hawkins 1982, 45, 55; see also Le Baron Bowen 1949, 91; Horridge 1979, 26, 28-9).
[484] Friedman and Zoroğlu 2006, 109, Fig. 2. The smaller vessel's sail appears to be a square sail, but the other details of the rig resemble a settee or quadrilateral sail; perhaps this is due to a mistake by the artist?
[485] Pomey 2006, 329.
[486] Pomey 2006, 329; see also Basch 1997, 216-17.

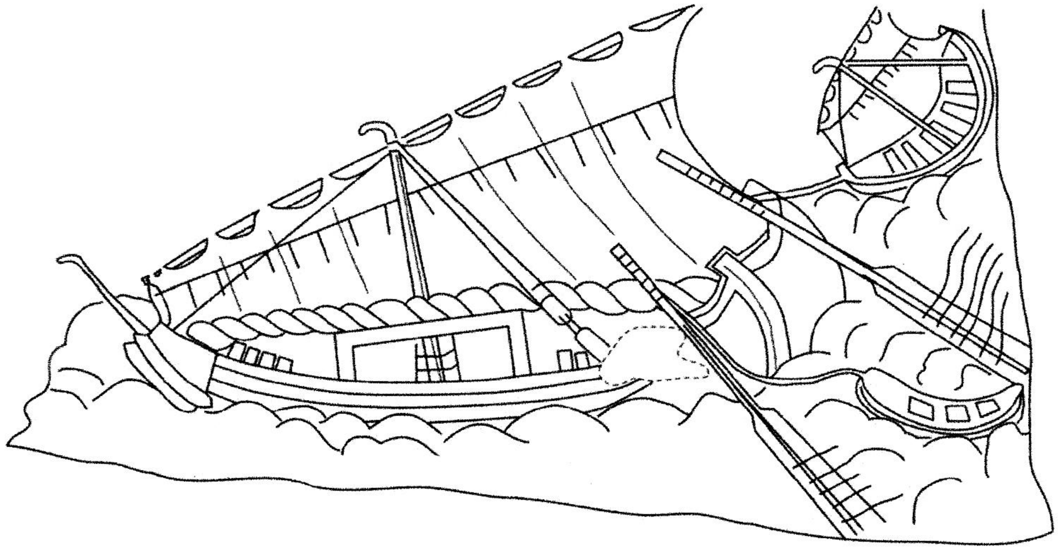

Figure 5.12: The Kelenderis mosaic, showing a fore-and-aft-rigged ship of the fifth or sixth centuries C.E. Note the pair of quarter rudders, the supports lashed to the base of the mast, the halyard with blocks, the beaked mast cap, the settee sail, and the band of reef points across the sail (After Pomey 2006, 326, Fig. 1).

Another detailed graffito dating to c. 600-630 C.E. comes from the monastic complex at Kellia, about 60 km southeast of Alexandria (**Figure 5.13**).[487] The Kellia graffito also shows a two-masted settee-rigged ship with a pair of halyards running through a hook-shaped mast head, a pair of blocks near the foot of the halyards, and a tabernacle or *xylokastron* around the mainmast.[488]

[487] Basch 1991b; 1993, 35, Fig. 25.
[488] Basch 1991b, 2.

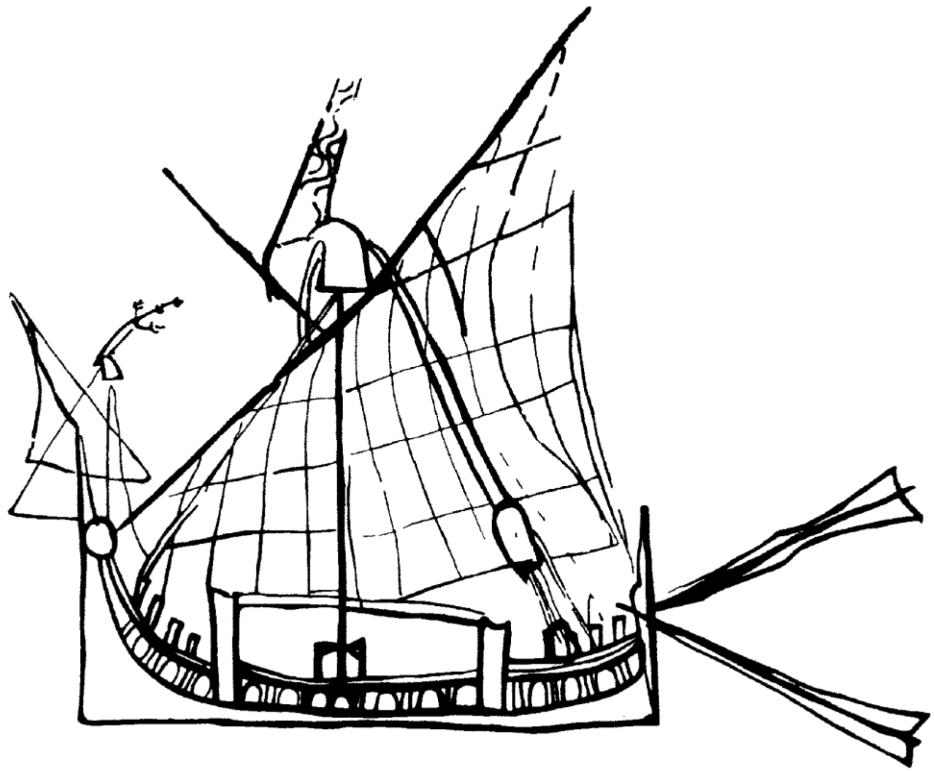

Figure 5.13: Byzantine ship graffito from Kellia, early seventh century C.E. (After Basch 1991a, Figure 1).

Although the sails are not raised in a fifth- or sixth-century ship graffito found at Corinth (**Figure 5.14**), the ship has many features in common with the Kellia graffito and Kelenderis mosaic. These similarities include the heavy halyards running to a double-sheaved block built into the hook-shaped mast head, a single forestay, a yard for the mainmast approximately equal to the length of the ship, upright supports on either side of the mast, short bitts near the bow, and a small foremast with similar masthead features as that of the mainmast.[489] The circles in the mast heads are shown one above the other,

[489] Basch 1991a; 1993, 38, Fig. 4; see also Whitewright 2012, 6. The smallest lateen-rigged vessels may not have needed a block in the mast head (Pryor 1994, 71). It is possible that these vessels may have had

perhaps as an attempt by the artist to show both sheaves for a pair of halyards mounted in the mast head itself. A twelfth-century depiction of a dromon with a *siphon* for Greek fire in the twelfth-century manuscript of the chronicle of John Skylitzes (Bibliotheca Nacional, Madrid, Vitr 26-2, fol. 34v) shows a mast head with two adjacent vertical lines, probably for a pair of sheaves for the halyards.[490] A small circle in the hook-shaped mast head of the ship on the Pala d'Oro in San Marco Cathedral, Venice (c. 1100), may be the pin holding a pair of sheaves as well (**Figure 5.15**).[491] Pairs of sheaves built into the mast heads of lateen-rigged vessels are also standard in later periods. The main variation between early medieval practice and that of later periods appears to be the differences in the shape and construction of mast heads rather than a conceptual difference in their design.

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hook-shaped or rounded mast caps without blocks in the mast caps themselves, a design implied by Pryor (1994, 71), instead having a single block near the mast head, as in the depiction of a vessel in a ninth-century Byzantine manuscript in the Moscow Library, the Khludov Psalter (see also Pryor and Jeffreys 2006, 244-45).

[490] Pryor 1995, 105.

[491] Martin 2001, 55, Fig. 29.

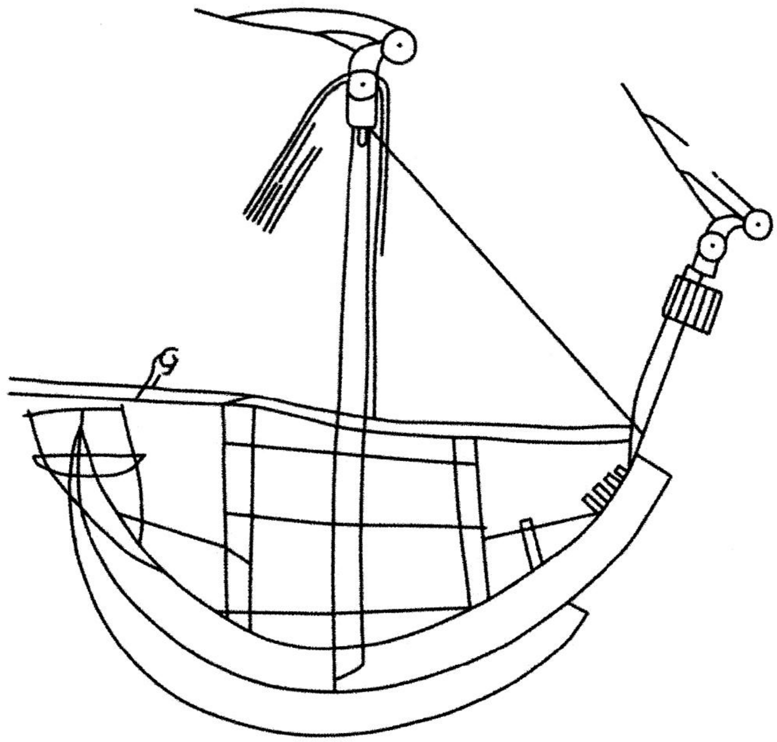

Figure 5.14: Fifth- or sixth-century C.E. ship graffito from Corinth (After Basch 1991b, 17, Fig. 8).

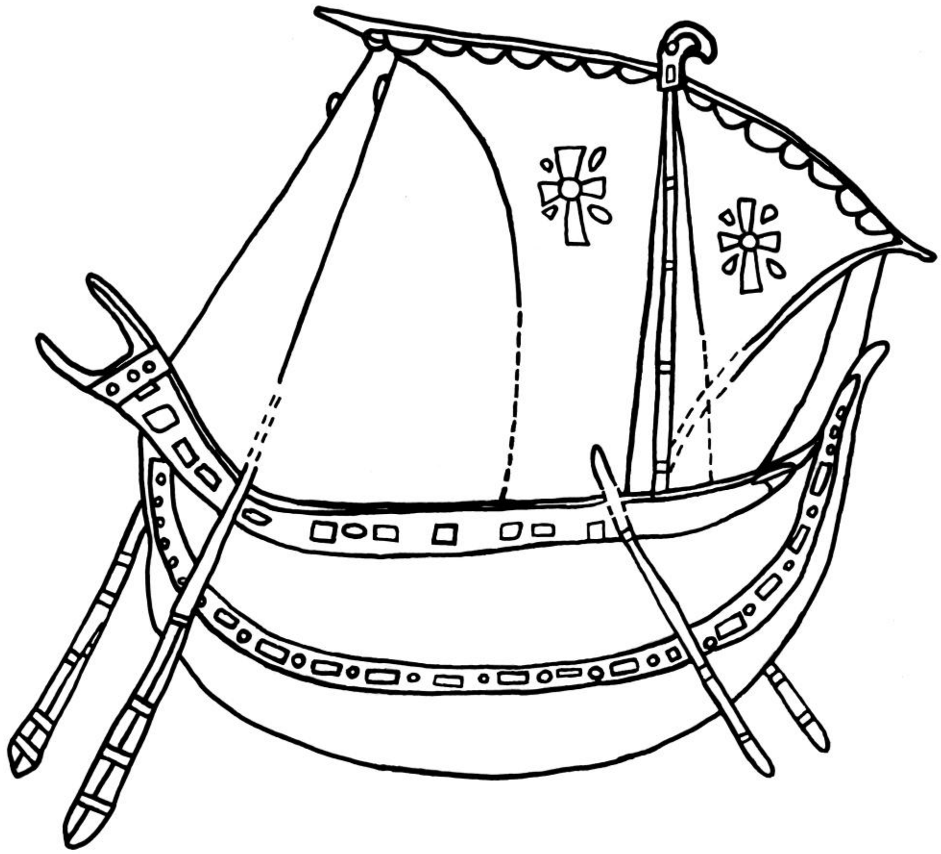

Figure 5.15: Details of an early medieval Mediterranean ship from a panel on the Pala d'Oro in San Marco, Venice, made by Byzantine artists around 1105 (Adapted from Martin 2001, Fig. 29). The ship is steered with a pair of quarter rudders (at left; the sweeps at right may have aided in tacking) and is propelled by a triangular lateen sail on a single mast (Martin 2001, 56).

Based on these ship representations, the lateen or settee rig's major characteristics were established by the fifth or sixth century.[492] However, a few further changes are evidence in lateen-rig depictions from the ninth century. Several of these depictions are of

[492] Whitewright 2009, 100.

triangular lateen sails rather than those of settee sails. The foremast is no longer shown, and the upright supports around the mast are simpler arrangements than those seen on the Kelenderis, Kellia, and Corinth depictions. The closest iconographic parallels to YK 14's probable sailing rig are found in Byzantine manuscripts dating from the ninth to twelfth centuries. A manuscript of the Sermons of St. Gregory of Nazianzos (Paris Bibliothèque Nationale, Ms. Grec. 510, fols. 3r & 367v) contains several miniatures of ships with fairly detailed masts and rigging, including double halyards running aft from the hook-shaped mast head of the vessels (Figures **5.16-7**). The manuscript has been dated to c. 879-82, with a provenance in Constantinople.[493]

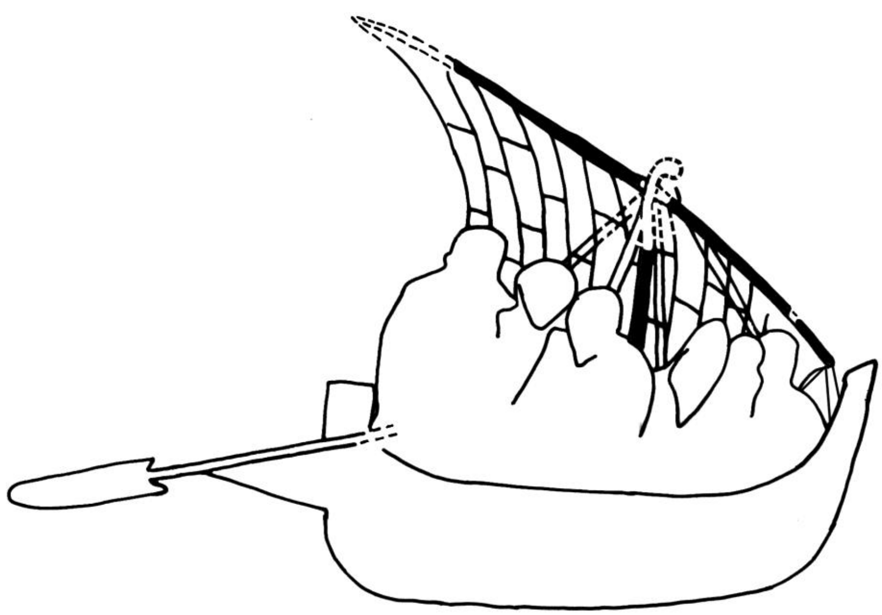

Figure 5.16: Byzantine ship, c. AD 880; from a manuscript of the *Sermons of St. Gregory of Nazianzos* (Bibliothèque Nationale, Paris manuscript gr. 510, f. 367v) (After Basch 1991b, 14, Fig. 2; see also Omont 1929, Pl. LII).

[493] Omont 1929, 10, Pl. XV-LX; see also Brindley 1926, 11-3.

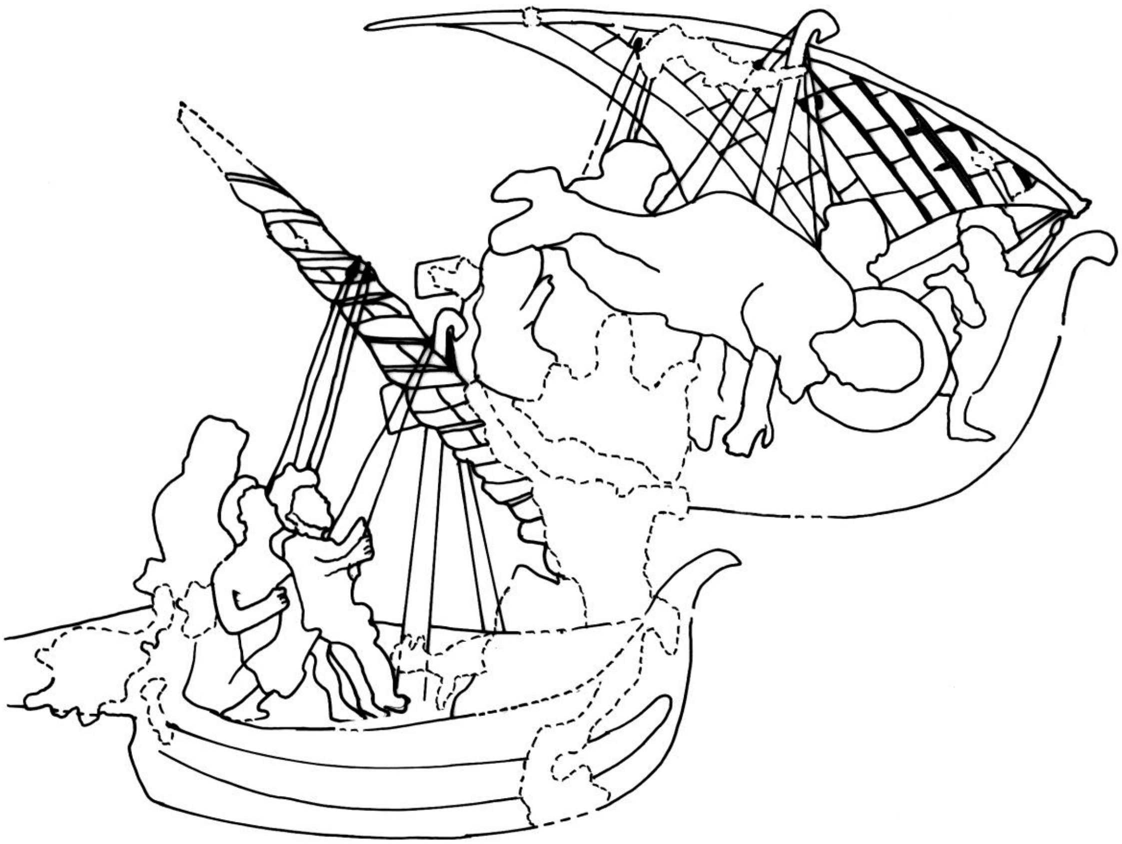

Figure 5.17: Scene from the tale of Jonah, from the *Sermons of St. Gregory of Nazianzos*, Paris gr.510, f. 3r, Bibliothèque Nationale, Paris, c. AD 880 (After Omont 1929, Pl. XX).

A slightly earlier depiction of a settee rig, probably for a much smaller vessel, is found in the Khludov Psalter (Moscow Historical Museum, MS 129 D, fol. 88r); this manuscript was also produced in Constantinople, possibly between 843 and 847 (**Figure 5.18**).[494]

[494] Omont 1929, Pl. LII; see also Pryor and Jeffreys 2006, 157-59.

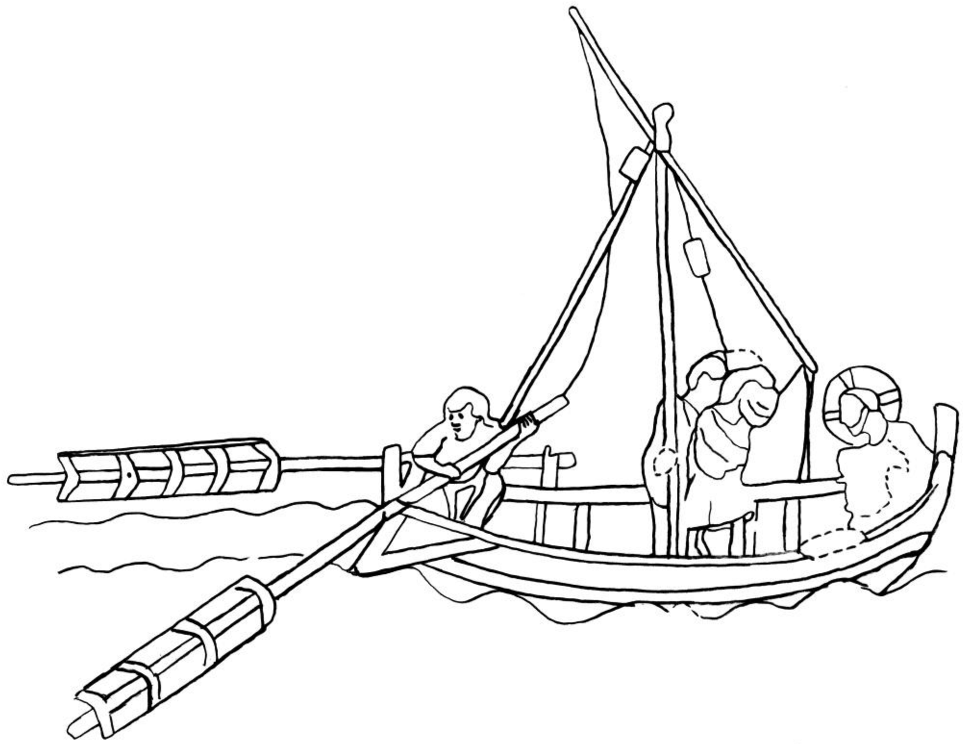

Figure 5.18: A mid-ninth century depiction of a Byzantine lateen-rigged vessel from the Khludov Psalter (After Zafiropoulou 1998, 38).

Another lateen sail representation is seen on an amphora from the Yenikapı site (YKM. 07. 4388) discovered in a stratigraphic layer dated to the ninth century (**Figure 5.19**).[495] The ship graffito was probably incised on the amphora before firing.[496] Although the shape of the ship's hull is substantially different from that of YK 14, and the representation is rather crude overall, the details of the rig are similar to those from other sources. The vessel is shown with a crescent-shaped hull, a single steering oar or quarter rudder, and a canted lateen yard with a hook-shaped mast head; a set of lines near the

[495] Günsenin and Rieth 2012, 157, 160.
[496] Günsenin and Rieth 2012, 160.

stern at deck level may represent a cabin (?), and roughly parallel lines on the sail seem to represent the individual sail cloth strips comprising the sail.[497]

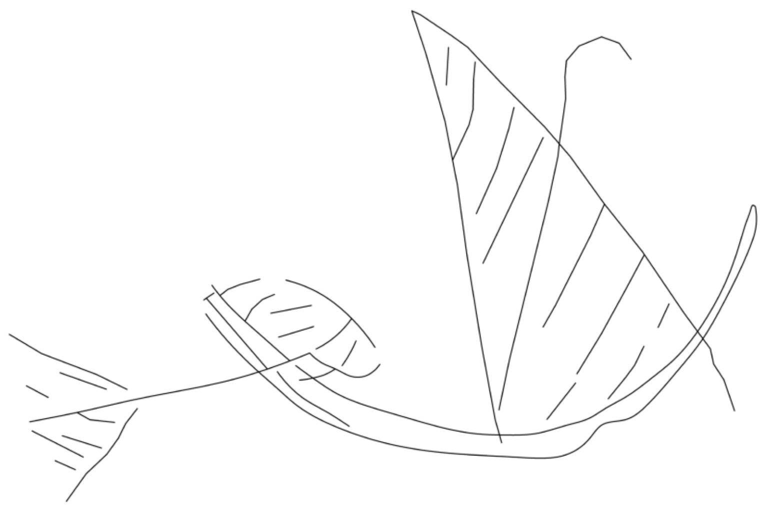

Figure 5.19: Graffito a single masted lateen-rigged ship from a piriform amphora from Yenikapı (YKM 07.4388), dated to the ninth century. Note the 'beaked' mast cap and the rudder blade's shape (After Günsenin and Rieth 2012, 160, Fig. 6).

In other ship depictions, a more rounded mast head was used; perhaps this form was intended to ease the swinging of the yard around the forward side of the mast (**Figure 5.20**). The hook-shaped mast head continued in use until at least the later twelfth century, when it was replaced by a box-like attachment.[498] This change may have coincided with an increase in the size of lateen-rigged ships.[499] Several later depictions of lateen-rigged vessels, primarily from the eleventh and twelfth centuries, provide

[497] Günsenin and Rieth 2012, 160, Fig. 5-6; see also Gökçay 2007b, 24.
[498] Martin 2001, 35-6, 52-6, 61.
[499] Pryor 1994, 71; 2000, 29-32.

specific details not seen in the earlier examples; these depictions will be discussed in the description of YK 14's rig where relevant.

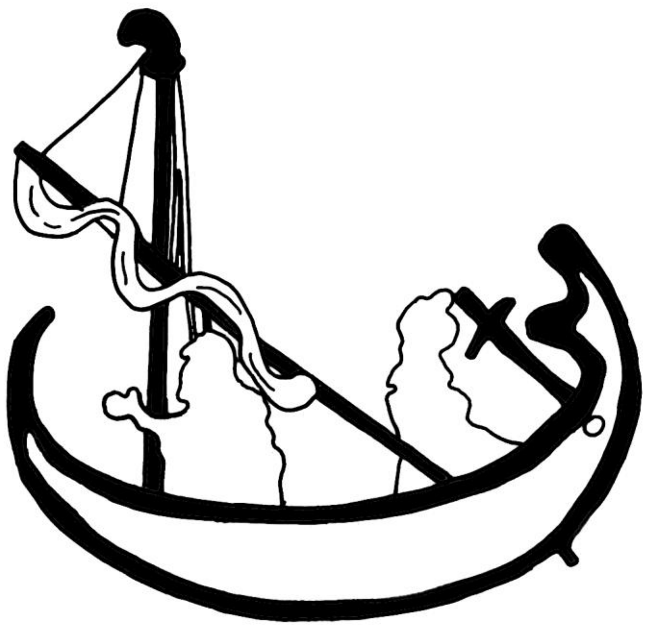

Figure 5.20: A small Byzantine lateen-rigged vessel depicted in an eleventh-century manuscript from the Church of Giorgio del Greci, Venice (lectionary folio 63 ro). Note the pair of halyards, particularly where they emerge from the hook-shaped mast head, and the furled sail (After Martin 2001, 61, Fig. 35).

4) Reconstruction of the Deck Features, Anchors, and Steering Assembly

One major assumption of the YK 14 reconstruction is an open hold amidships. Most Byzantine iconographic sources show open-waisted vessels of this sort, including the ships in the late ninth-century MS Grec 510 in the Bibliothèque Nationale, Paris.[500] On YK 14, it is possible that there was a small gangway inside the waist of the ship on either side to allow the sailors to easily pass from the bow to stern, but no evidence for such an arrangement was found. YK 14's internal structures were probably similar to those shown in a preliminary reconstruction of YK 1 (**Figure 5.21**). Most of the vessels' anchors were presumably stored in the hold, with perhaps a pair of bower anchors available on the foredeck. Although three-hole composite stone anchors with wooden stakes for flukes are very common finds at Yenikapı in contexts dating to the seventh-century C.E. and earlier, iron anchors seem to be standard in the ninth- and tenth-century for larger vessels.[501] 'Y'-shaped wrought-iron anchors such as those used on the Serçe Limanı ship and on YK 1 are found in layers dating to the tenth-eleventh century at Yenikapı; 'T'-shaped iron anchors are found as well, generally in earlier levels.[502] 'Y'-shaped anchors would have been used on YK 14 (**Figure 5.22**).

[500] Brindley 1926, 11-3. This manuscript is the Byzantine source closest in date to the date of YK 14's construction. A *qārib*, or small Arab merchant vessel, is explicitly described as undecked in a mid-eleventh century Cairo Geniza letter; since the word for this type of vessel comes from the Greek *karabos*, it suggests that the vessel is originally a Byzantine type (Goitein 1967, 305-6; see also Pryor 2000, 28).
[501] The vernacular tenth-century term for anchor was 'iron' (*sidēron*), used in the naval inventories in the *Book of Ceremonies* and other sources (Pryor and Jeffreys 2006, 210-11). For examples of stone anchors from Yenikapı and other Marmaray Project sites, see Çölmekçi 2007, 237; Karagöz 2010, 106, Fig. 15 (for stone anchors from Sirkeci on the Golden Horn).
[502] Bass et al. 2004, 229-30; see also Bass and van Doorninck 1982, 126-31, 134-41; Steffy 1982a, 69. AN 7, one of the bower anchors from the Serçe Limanı ship, was added to the YK 14 reconstruction as an example of the type of anchor that would have been used on the ship; it would have been equipped with a wooden stock, as shown on the reconstruction. The anchors from the Serçe Limanı wreck are nearly identical in size to those found on YK 1. The collar on the anchor stock and the wooden pin to hold the collar in place are conjectural.

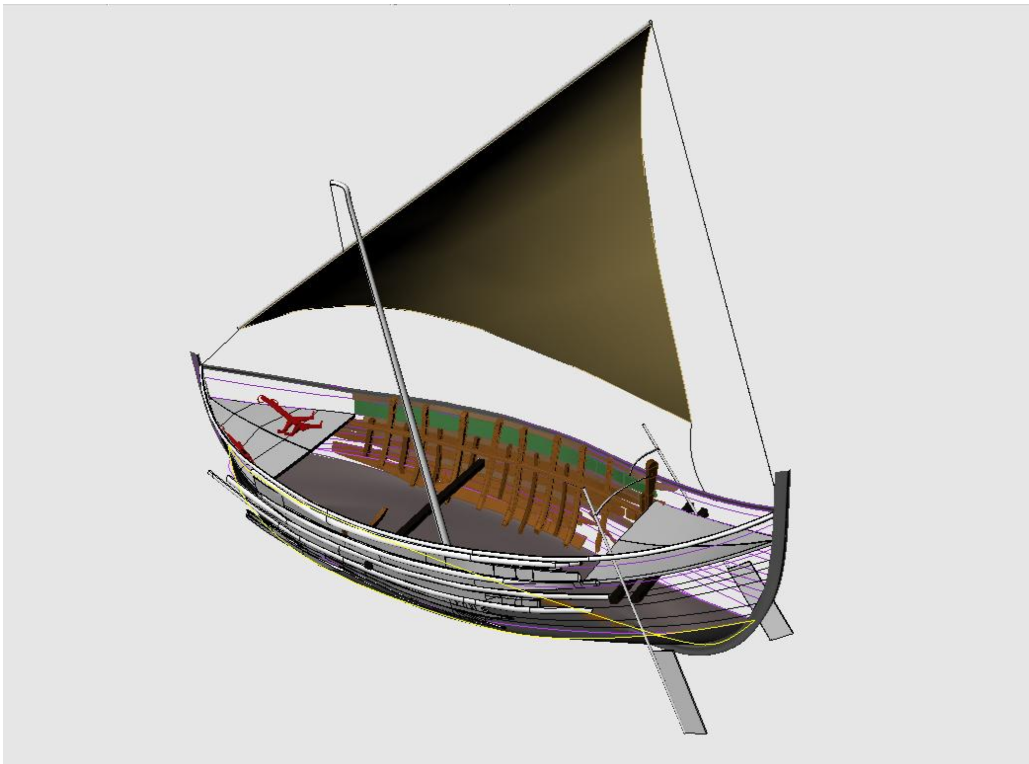

Figure 5.21: Preliminary reconstruction of tenth-century Yenikapı shipwreck YK 1. The preserved section of the hull is shown in brown and green. Anchors on the wreck indicate the bow; at least some of the anchors of YK 14 were probably kept at the same location. The general design of this vessel--small fore and stern decks, a single lateen mast with a mast partner, and a pair of quarter rudders--is probably the same as that on YK 14 (Model by Sheila Matthews).

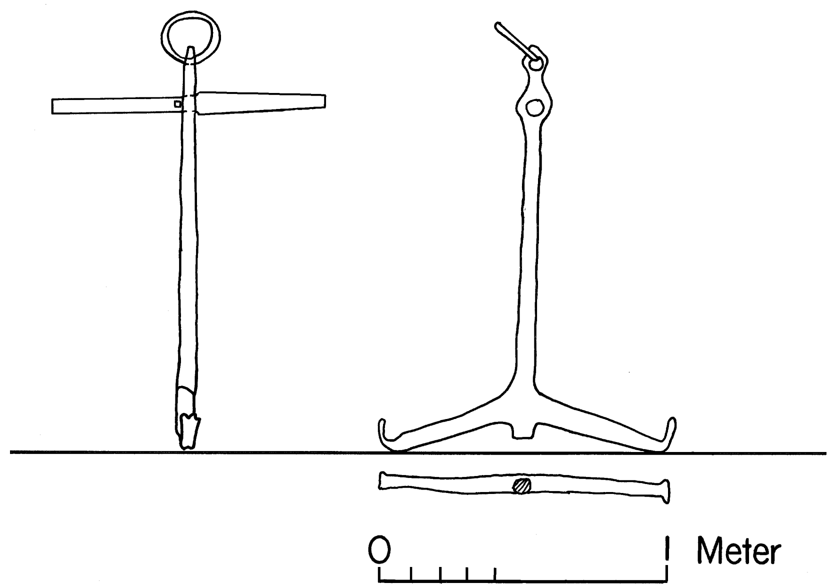

Figure 5.22: Reconstruction of a 'Y'-shaped iron anchor of the type that would have been used on YK 14. The stock, which would have been made of wood, is hypothetical (Adapted from Bass et al. 2004, Fig. 12-11, 229).

Anchors were stored on deck on the seventh-century Yassıada ship and the Serçe Limanı ship; the Yassıada ship carried eleven, while the Serçe Limanı ship carried at least nine anchors.[503] On both shipwrecks, a pair of anchors was found on either side in the bow area, ready for use, similar to the placement of the two anchors on YK 1; impressions of wooden anchor stocks were found in the iron anchor concretions, although a few iron stocks were also carried on the Yassıada ship.[504] This practice was probably followed on

[503] Bass et al. 2004, 196-215, 230-31; see also Bass and van Doorninck 1982, 124-31, 134-37; Steffy 1982a, 69.

[504] Bass et al. 2004, 188-90, 229-32; see also Bass and van Doorninck 1982, 126, Fig. 6-12, 133, Fig. 6-24, 138. A possible Byzantine-era anchor stock found on the Yenikapı was constructed of wood with four lead inserts. The object is 2.2 m long and approximately 8.6 cm in diameter (Gökçay 2010, 150). A similar

YK 14 as well, perhaps with additional anchors stored elsewhere on the ship. A coaster such as YK 14 would have likely carried fewer anchors than the Yassıada and Serçe Limanı ships, which were used for longer voyages. Anchor cables, perhaps of linden bast rope or hemp, would have been kept in the bow as well, in the same area as a coil of rope on YK 1.[505] Futtocks protruding beyond the caprail in the bow could have perhaps been used as bollards for securing the anchor cable.

YK 1 and YK 5 cargo vessels of similar size to YK 14, each displayed evidence in the surviving hull for only a single through-beam amidships, which most likely served as a mast-partner beam on both vessels. A similar feature was probably positioned amidships in YK 14's hull as well.

A higher deck was built at the stern as a platform for the helmsman and for other sailors handling the rigging. A space here would be required for hoisting the yard using the halyards and adjusting the vangs running to the peak of the yard. In this period, Mediterranean ships were steered with a pair of quarter rudders or steering oars. Many depictions of vessels dating from the sixth to the thirteenth centuries give us a general idea of the shapes of quarter rudders in this period.[506] On the reconstructed hull of YK

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wooden anchor with lead inserts was also found in Tantura Lagoon on the coast of Israel (Wachsmann and Kahanov 1997, 11, 13).

[505] Anchor cables of what is probably linden bast rope are listed in the 911 and 949 naval inventories of equipment for dromons in the *Book of Ceremonies*. Linden bast may have been chosen specifically for anchor cables, perhaps due to its resistance to rotting in water (Pryor and Jeffreys 2006, 212-13). See also Chapter VI.

[506] Mott 1997, 56; see also Zafiropoulou 1998, 37-8, 70, 82, 84; Martin 2001, 55, 61; Friedman and Zoroğlu 2006, 109, Fig. 2; Basch 1991b, Fig. 1.

14, the steering oars are lashed to a pair of through-beams in a brace mount, one of the simpler arrangements attested in this period.[507] A single protruding through-beam was used on the Port Berteau ship, a coaster that capsized and sank at the mouth of the Charente River on the Atlantic coast of France around 600 C.E.[508] Box mountings for quarter rudders were popular in earlier periods and continued to be used into the Middle Ages, but this design is slightly likely more elaborate that the design used on YK 14.[509] Byzantine artists sometimes show only one quarter rudder in use at a time (see Figure 7); this practice is also followed on some traditional Indonesian vessels steered with a pair of quarter rudders.[510] Merchant vessels shown in Byzantine art are steered by a single helmsman.

Many depictions also show a pair of oars in use in the bow of the ship as well.
This may have been a practice only for smaller vessels, but YK 14 could have had auxiliary oars, perhaps used for maneuvering the ship in harbors or in unfavorable wind conditions, or for assistance in changing tack.[511] Auxiliary oars may have been common on small coasters mentioned in the Cairo Geniza letters, as well as on Amalfitan sailing vessels called *sagenae*; such a combination would be practical for small merchant ships

[507] Mott 1997, 21.
[508] Rieth et al. 2001, 43, 61-2, Fig. 58; see also Pomey et al. 2012, 263-64.
[509] Mott 1997, 73, 77; see also Pryor and Jeffreys 2006, 220-24.
[510] Burningham 2000, 100-1. Steffy (1985, 254-55) notes that the use of a single quarter rudder was more efficient for the Kyrenia replica in some conditions at sea. In testing quarter rudders on a scale model of the seventh-century Yassıada ship’s in hydrostatic tanks, Steffy noted that the hull was much more difficult to handle with both quarter rudders in use than a more modern stern rudder, although the results depend greatly on the shape and angle of the quarter rudders (Steffy 1982a, 85). Perhaps the quarter rudders were designed to be used one at a time in calm weather, with one oar in reserve.
[511] Martin 2001, 56.

engaged in *cabotage* trade along the coast.[512] Oar ports in the bow and stern of the Skuldelev 1 ship, an eleventh-century Viking cargo carrier, show that auxiliary oars were used on similarly-sized ships in northern Europe as well.[513] The narrowness of YK 14's hull may have been an advantage in rowing, and auxiliary oars would have likely been useful for coping with the strong currents on the Bosporus and the Sea of Marmara.

The quarter rudder on the YK 14 reconstruction is based on an enamel panel from the *Pala d'Oro*, the altar in San Marco, Venice, made by Byzantine artists and dating to c. 1105 (see **Figure 5.17**).[514] The quarter rudders of the vessel seem to be quite narrow in comparison to earlier designs, and appear to be made from a pair of timbers lashed or strapped together. Parts of the rudder blades appears to be fastened to the main oar shaft with iron or copper alloy straps held in place with nails or rivets. Presumably the pieces were mortised or pegged together as well, similar to the design of earlier quarter rudders.[515] The width of the reconstructed quarter rudder blade (38 cm at its widest) is similar to that of the single quarter rudder blade recovered from the Kyrenia ship, which is 32 cm wide.[516] Quarter rudders in the Mediterranean underwent major design changes between the sixth to eleventh centuries C.E., so there are a range of possibilities for the

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[512] Goitein 1967, 305-6; see also Kreutz 1976, 101-3. Pryor (2000, 27-33) suggests the use of oars on commercial vessels was a way to compensate for relatively poor sailing performance.
[513] Crumlin-Pedersen 2002, 119, 137.
[514] Martin 2001, 55; see also Zafiropoulou 1998, 82.
[515] Steffy (1985b, 254, 261) notes evidence in the form of corrosion stains on the quarter rudder blade recovered from the Kyrenia ship, as well as mortises in the blade for attaching it to the loom (see also Ucelli 1950, 168, for a second example of quarter rudder blades mortised to the quarter rudder's shaft).
[516] Steffy 1985b, 254.

design of those used on YK 14.[517] A ship in the Paris manuscript of St. Gregory of Nazianzos depicts a single quarter rudder of an older design; this type is arguably more appropriate for the reconstruction of YK 14, although this depiction may be a copy of an older manuscript as well.[518]

5) Reconstruction of YK 14's Rig

For the reconstruction, the mortises at FL 22 and 28 were used for the placement of the mast step. In-situ mast steps survived on only a few of the 36 shipwrecks discovered at Yenikapı; only one of these vessels, YK 24, was investigated by the INA team.[519] This vessel was a small cargo vessel with an estimated length of eight meters, so this mast step may be slightly smaller than the one used on YK 14.[520] More importantly, it has only a single mortise in its inner face, unlike mast steps for some larger vessels.

YK 14's mast was stepped roughly amidships, which is consistent with the use of a single lateen sail.[521] It probably resembled those found on YK 12 and YK 20, ships documented by Istanbul University.[522] Of the two, the short YK 20 mast step, rather than the elongated mast step from YK 12, is probably a closer parallel; there are no fastener

[517] Mott 1997, 54-63.
[518] Some scholars believe the manuscript is copied from a fifth-century original and warn that some details may be apocryphal (Zafiropoulou 1998, 37). However, the differences in the rigs of these vessels compared to earlier depictions seem to indicate that the details of the rigs at least are fairly contemporaneous (Polzer 2008, 246; see also Whitewright 2009, 100).
[519] Özsait-Kocabaş and Kocabaş 2008, 111, 115).
[520] The mast step on YK 24 was preserved to a length of about 1.2 m. One end was damaged, so the original length is an estimate, perhaps 1.4-1.6 m. The mast step is approximately 15 cm wide, and 8 cm thick, with a single rectangular mortise about 6 cm deep, with part of the mortise penetrating the entire thickness of the mast step. The intact end was nailed in place with a pair of nails.
[521] See, for example, Howarth 1977, 47, and Weismann 1998, 254.
[522] Özsait-Kocabaş and Kocabaş 2008, 114-15; 2012a, 111, Fig. 15.11.

holes or pressure marks that could have been caused by an elongated mast step on YK 14's floors forward and aft of the mast step mortises located on floors FL 22 and 28, with the possible exception of a pitch impression found on FL 21 (see Chapter III). The YK 12 mast step also may have been used for a spritsail rather than a lateen sail with a support post.[523] The use of a shorter mast step with two mortises is well attested ethnographically on lateen-rigged Arab dhows and Mediterranean lateen-rigged craft (**Figure 5.23**).[524] There are also several parallels from other archaeological sites and in Byzantine art. Shipwreck D, a sixth-century wreck discovered in an anoxic environment on a deepwater survey of the Black Sea coast in 2000 conducted by Robert Ballard, exhibits a perfectly preserved example of this structure. The mast, estimated as 11 m long, is supported by an upright post protruding from the deck and presumably held in place by a mast-partner beam and the deck planking.[525] Similar supports are shown in the Kelenderis mosaic, the ship graffito from Corinth, and the ship graffito from Kellia; all three depictions show upright members or posts around the mast, as well as a possible larger structure which is no longer evident in later ship depictions.[526] The Tantura F shipwreck's mast step has a second mortise; it is flanked by two transverse mast-step

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[523] Özsait-Kocabaş and Kocabaş 2008, 114-15. Cemal Pulak identified this mast step as being configured for a spritsail, which would also require two mortises (one for the mast and one for the spritsail boom) (C. Pulak, personal communication).
[524] Basch 1991b, 7; see also Villiers 1962, 120; Jewell 1969, 92; Hawkins 1977, 28, 47, 52, 64, 67, 77-80, 87, 94-5; Marquardt 1992, 162; Al-Hijji 2001, 12, 58 (for modern photographs of a Kuwaiti *boum*'s mast step, very similar to Byzantine examples). See Le Baron Bowen (1949, 110) for a plan of an open-waisted *jahlbut* with an upright mast support, similar to the probable design of Byzantine vessels.
[525] Ward and Ballard 2004, 9-10; see also Ballard et al. 2001, 618-21. Unfortunately, silt and the ship's deck partially obscure the structural details.
[526] Whitewright 2009, 98-9; see also Friedman and Zoroğlu 2006, 108; Mor and Kahanov 2006, 281; Pomey 2006.

sisters with single mortises that may have supported additional stanchions or struts.[527] The same arrangement was also used on the Dor 20001/1 ship, a flat-bottomed stone carrier dating to the fifth or early sixth century, although only a single mast step sister remains.[528]

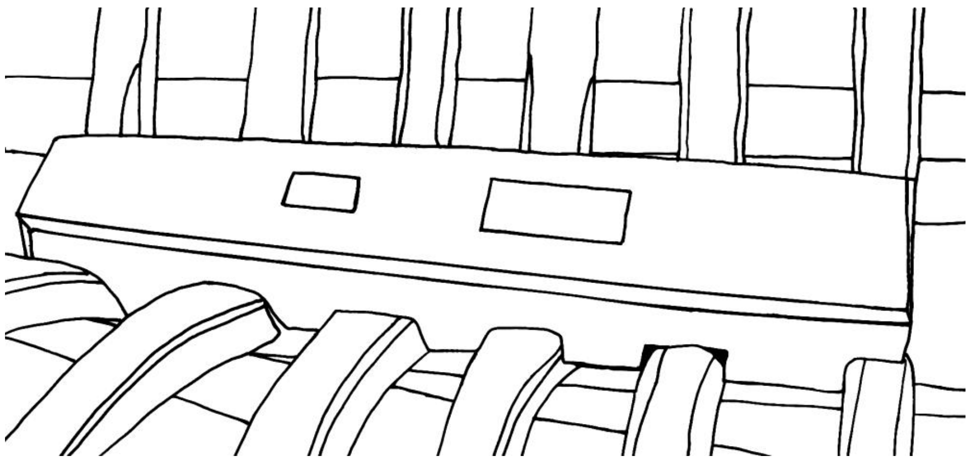

Figure 5.23: Mast step from a modern Kuwaiti *boum*. The vessel's mast is lateen-rigged, and is lashed into a post mortised into the smaller mortise in the mast step, with a mast partner in between (After Al-Hijji 2001, 58).

No evidence for such transverse supports at the mast step were found on the INA-documented shipwrecks at Yenikapı except possibly the seventh-century ship YK 11, on which mortised blocks possibly used as sister keelsons were found amidships. Since YK 11 is one of the earlier shipwrecks excavated at the site, it is possible that this arrangement had fallen out of use by the ninth century.

[527] Barkai and Kahanov 2007, 24, 26, Fig. 9.
[528] Mor and Kahanov 2006, 274, 281.

On YK 14, the exact position of the mast-step mortise in relation to the ends of the mast step timber is conjectural. For the reconstruction, a distance of 24 cm between the mast step and stanchion mortises was chosen, based on the Tantura F mast step and in order to give the mast a slight forward rake of approximately 10-11 degrees. Single-masted dhows typically have masts placed close to the center of the hull and angled forward between 10 and 20 degrees.[529] The YK 14 mast step is reconstructed as 1.64 m long, 18 cm wide, and 10-20 cm thick. The mast on the reconstruction is lashed in place to the stanchion on the opposite side of the mast partner. The rope used for the lashing on the reconstruction is approximately 2.5-3 cm thick.

The Mast and Yard

The dimensions of the mast and yard were somewhat more difficult to determine. Archaeological examples of masts from ancient and medieval ships are extremely rare. The mast of the sixth-century Shipwreck D found on Ballard's Black Sea expedition in 2000 was estimated at approximately 11 m long, and the ship's hull at approximately 12-14 m in length and 3.5-4 m wide, or approximately the same size as YK 14; Ward and Ballard state that the vessel was probably lateen rigged.[530] The mast was not directly measured, however, and its height seems excessive; several sources concur that the masts on Arab dhows are relatively short in relation to the length of their yards.[531] Little evidence of ancient and medieval ships' masts have been found. A Roman period mast

[529] Dimmock 1946, 37. For examples of raked masts on dhows, see Howarth 1977, 25, 33, 34, 47, 85.
[530] Ballard et al. 2001, 619; Ward and Ballard 2004, 10-2.
[531] Dimmock 1946, 37. Dimmock describes the masts of dhows as "short" and "thick", an observation also made by Howarth (1977, 89, 110). A shorter raked mast would more easily support such a large yard and sail.

from Olbia in Sardinia is much too large for a vessel the size of YK 14; Riccardi proposes that it was for a 30-35 meter long vessel.[532] The 55 cm-long base of a mast was also found on the fifth-century C.E. Dramont E ship, a ship whose original dimensions have been reconstructed as 14.1 m in length and 6.15 m in beam.[533] The cross-section of the Dramont E mast at its base is approximately 27.5 cm x 23.5 cm, with a 6.5 cm-wide tenon cut into the base of the mast to fit in the mast-step mortise.[534] Preliminary investigation of Dor 2006, a sixth-century C.E. shipwreck at Dor/Tantura, has revealed an upright timber, possibly a mast, 26.1 cm in diameter.[535] A mast was also found on the Romano-Celtic Bruges boat (second/early third century C.E.), which was at least 9.3 m long and had a maximum diameter of about 16 cm. Although this mast was for a square-rigged vessel from northern Europe and probably showed little Mediterranean influence in its design, it at least gives some idea of mast size and diameter for a small Roman-period ship used as a coaster or river vessel.[536]

The diameter of YK 14's reconstructed mast at its base was determined largely by the width of the mast step. A diameter of 18 cm was chosen for the base of the mast, in order to have a mast reasonably strong and yet not too heavy for the light scantling of YK 14. A relatively small mast also seemed suitable considering the small size of the few mast

[532] Riccardi 2002, 268-9. The possible mast timber dates to the first century C.E., survives to a length of about 7.6 m, and is 42 cm in diameter. A set of mortises cut along opposite sides of the timber for about half of its preserved length are very similar to those on a quarter rudder from one of the Nemi ships, leading C. Pulak (personal communication) to identify the timber as a probable quarter rudder loom for a large ship rather than a mast (Riccardi 2002, 269, Fig. 3; see also Ucelli 1950, 168, Fig. 179).
[533] Santamaria 1984, 107; see also Poveda 2012, 332. Santamaria (1984, 107) estimated the ship's original dimensions as 15-18 m in length and 6 m in beam.
[534] Santamaria 1984, 110.
[535] Navri 2011, 57.
[536] Marsden 1976, 23-4, 29-30, 40-2; 1994, 67-9.

steps preserved on the Yenikapı ships from the ninth and tenth centuries. This aspect of the construction is conjectural and could be plausibly modified; for example, a heavier mast step may have been necessary.

Fifteenth-century Venetian manuscripts such as the nautical text of Michael of Rhodes and a later excerpt of Michael of Rhodes' text known as the *Fabrica di Galere* provide evidence for formulas for the size and proportions of masts and lateen yards.[537] Byzantine sails and yards probably used very similar proportions, but without actual examples it is difficult to determine what sort of proportions might have been used. For a small merchant vessel such as YK 14, it seems likely that a relatively simple configuration was used. Another problem when applying later formulas is that both the formulas from the *Fabrica di Galere* and the Michael of Rhodes manuscript are for ships with multiple masts. The exact proportions published from the *Fabrica di Galere* manuscript are for a much larger, two-masted vessel; similar proportions were also used for lateen-rigged craft, while the Michael of Rhodes manuscript provides dimensions for lateen masts and yards for various two-masted ships, some of which are incomplete or very difficult to interpret.[538] Although set proportions for the size of sails and yards may be used from these manuscripts, the dimensions themselves should be used with caution. One rule from *Fabrica di Galere* was followed in the reconstruction: the diameter of a mast at the point where the rigging is attached to the mast should be 2/3 of the diameter

[537] Pryor 1984; see also Bellabarba 1988. For a translation of the Michael of Rhodes manuscript, see Long et al. 2009. For the sources of the Michael of Rhodes text and *Fabrica di Galere*, see McGee 2009, 211, n.1.
[538] Bellabarba 1988, 115-16, 119-20.

at its base.[539] Since the YK 14 mast is reconstructed as 18 cm in diameter, the tip of the mast is therefore reconstructed as 12 cm.

The length of the yard of single-masted Arab dhows is typically about the length of the hull or longer, although photographs and drawings of various types of modern dhows and Mediterranean lateen-rigged craft show a great deal of variation.[540] A settee rig could use a slightly shorter yard, but, following the iconography of Byzantine ships closest in date to the construction of YK 14, a lateen sail was used for the reconstruction (see Figures 5.18-9).[541] The pieces of the yards would probably be made of a strong, flexible timber such as pine or fir.[542] Byzantine ship representations, particularly those from the manuscript of St. Gregory of Nazianzos from the Bibliothèque Nationale in Paris dated to c. 880 (Ms. Gr. 510) depict a lateen sail on a yard about as long or longer than the hull of the vessel.[543] The common observation that the main yard of a lateen-rigged vessel is approximately equal to the ship's length was used as a general guide in the reconstruction of YK 14. The proportions of the two main pieces of the yard were calculated using a formula from *Fabrica di Galere* for the construction of a complete lateen yard. This document describes a lateen yard (either for a fully lateen-rigged or a

[539] Bellabarba 1988, 119.
[540] Le Baron Bowen (1949, 103) describes the yards of single-masted *jahlbuts* of the Persian Gulf extend from the end of the bowsprit (itself "projecting from twenty-five to thirty percent of the overall hull length") to just beyond the stern of the vessel. The vessels in Byzantine iconography lack bowsprits, so their lateen yards would have been shorter. Weismann (1998, 242, 255), in his study of the Omani *beden Al-Khammam*, calculates the length of yard of a hull of a settee sail as about 22 m for a ship 17.5 m in length based on information on the number and width of sail cloths used in the vessel's sail.
[541] See Zafiropoulou 1998, 37-8, 70, 82, 84.
[542] Theophr. *Hist. Pl.* V. I.1.
[543] Paris Ms. Gr.510, f.367. (Omont 1929, Pl. LII). This depiction is extensively cited: see also Brindley 1926, 13; Le Baron Bowen 1949, 93; Bass 1972, 149.

mixed-rig ship) as being made up of two pieces, the *stelo* and the *ventame*.[544] The *stelo* is the lower, heavier part of the yard, and is about 2/3 the length of the *ventame*, which is also seven-tenths of the length of the entire yard. The two arms overlap for about one-fifth of the total length of the yard, and the overlapping area is seven-fifths of the thickness of the rest of the yard.[545] Thus, the two arms of the yard were 12.8 m (or approximately 40 Byzantine feet) long together, based on a 6.4 m *stelo* and an 8.96 m *ventame*, with an overlap of 2.56 m. The *stelo* and *ventame* were also tapered, so that the tips were about two-thirds of the diameter of the bases, using the same rule applied to the masts. For the reconstruction, the base diameters of the two main timbers of the yard were made slightly smaller in diameter than that of the mast, in order to make the yard lighter; this resulted in a *stelo* and *ventame* with diameters of 12 cm near the mast (before a beveled section on each piece where the two arms are fitted together) and 8 cm at their tips. Shallow notches were added in the yard where four sets of wooldings lashed the *stelo* and *ventame* together; similar notches are included on the ends of the yards (**Figure 5.23**).[546] When raised, the yard was probably slightly bent due to its own weight and the weight of the sail; this feature is seen in modern photographs of dhows under sail, and also seems to be shown in depictions of Byzantine ships.[547]

[544] Pryor 1984, 287.
[545] Bellabarba 1988, 119-20. See also Long et al. (2009:2, 383, 385-89, 433, 475, 509) for entries on the proportions of lateen masts and yards from fifteenth century vessels.
[546] Ward and Ballard (2004, 11) note a pair of possible spars on the deck of Shipwreck D; one has a semicircular tenon and a 20 cm hole drilled through it. It is possible that some sort of mortising was used for connecting different pieces of a lateen yard, but lashing is the best documented technique; this method appears to have been used on virtually all lateen-rigged vessels in later periods. On some Italian vessels, the wooldings were tightened by driving a wedge into the lashings with a hammer (Bellabarba and Guerreri 2002, 245, Fig. 15).
[547] Villiers 2006.

The yard dimensions produced from the formulas in the *Fabrica di Galere* resulted in a rather small sail in relation to the height of the mast; at amidships, there was a gap of 2.4 m between the top of the sheer strake or cap rail and the foot of the sail if the sail was reconstructed as a lateen rather than a settee sail due to the more frequent occurrence of this sail type in ninth- to twelfth-century depictions.[548] For this reason, two shorter timbers were added to the ends of the yard. Representations of Byzantine lateen-rigged ships closest in date to YK 14 do not clearly show the separate yard pieces; the yards on these vessels could have been constructed from a single timber up to four timbers. A merchant galley in folio 145B of the Michael of Rhodes manuscript (c. 1436 C.E.) has a lateen yard made of four pieces: two arms and two much smaller pieces lashed to either end of the yard.[549] A similar design was used on the YK 14 reconstruction. A yard made of three or four timbers, in the manner of many Arab dhows, is plausible for a rather inexpensive local coaster, and would allow for readjustment of the yard length if desired by the captain.[550]

Another area of potential problems is the cant of the yard and the shape of the sail. This varies significantly on single-masted lateen-rigged vessels: for example, the cant of the yard is quite steep on some Italian lateen rigs, and tends to be somewhat shallower on settee sails.[551] Based on the vessels depicted in the St. Gregory of Nazianzos manuscript

[548] Whitewright 2009, 98-100.
[549] Martin 2001, 83, 86.
[550] For multiple-piece yards on Arab dhows, see Le Baron Bowen 1949, 90; also Hawkins 1977, 25, 31, 69, 75, 93 (where a four-piece lateen yard is described as ‘customary’ on dhows), 121, 130; Howarth 1977, 86; Al-Said 1979, 119; Villiers 2006, 114-15, 122.
[551] Bellabarba and Guerreri 2002; see also al-Said 1979, 119.

and other examples in Byzantine art, the yard has been reconstructed at a somewhat shallow angle. Although consistent with contemporaneous as well as modern ethnographic sources, this is perhaps the single biggest problem in the reconstruction of the ship's rig. The relationship between the angles and lengths of the mast and yard is one of the most fundamental features of the vessel and profoundly affect the shape of the sail and the handling of the ship. Unfortunately, the lack of archaeological evidence and the vagueness of contemporary depictions of lateen-rigged ships are insufficient for producing a reconstruction of these features beyond an educated guess. A detailed study of the hull's hydrodynamic characteristics and stability could perhaps determine the dimensions and configuration of the ship's rig more precisely.[552]

The final part to the mast is its hook-shaped masthead or mast cap.[553] Mast caps, either with a beak-like point or a rounded knob, are clearly shown on artistic representations of lateen-rigged vessels from the sixth to the twelfth centuries, when more elaborate mast caps with crows' nests were introduced.[554] Several pieces of evidence indicate that the mast cap was a separate piece. A mortise is visible in the top of the preserved mast on Shipwreck D, a small lateen-rigged vessel discovered on Robert Ballard's deep sea survey of the Black Sea coast in 2000.[555] One entry in the 949 inventory for the Byzantine naval expedition to Crete in the *Book of Ceremonies* includes a request for 20

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[552] Although the Blackfriars ship was most likely sailed with a square rig rather than a fore-and-aft rig, Marsden's (1994, 67-74) attempts to reconstruct the Blackfriars ship's rig show the difficulties involved in calculating mast heights based on calculations used for later vessels. Different formulas and sources of evidence provide a wide range of possible heights for the ship's mast.
[553] Pryor 1984, 286.
[554] Whitewright 2009, 101; see also Brindley 1926, 10; Martin 2001, 55, 61, 64-7.
[555] Ward and Ballard 2004, 6-10.

chalkisia in the rigging equipment of 20 dromons; Pryor and Jeffreys (2006, 244-5) interpret this word as 'masthead' in this context.[556]

A 'beaked' mast cap with a pair of sheaves mounted next to each other is used on the YK 14 reconstruction; the 'beak' is similar to those on vessels in the ninth-century Gregory of Nazianzos manuscript, and less pronounced than those seen in other depictions. The halyard would have run through the beak, over a sheave reconstructed as about 14 cm in diameter.[557] The twelfth-century Cathedral of Monreale in Sicily appears to show several design details of this mast cap, which are not present in other representations (**Figure 5.24**).[558]

Based on this mosaic, YK 14's mast cap is reconstructed with a tenon at its base and notching into a mortise cut into the head of the mast; the mast cap would be held in place with several fasteners, probably iron bolts or treenails that could be easily removed. This is a somewhat speculative design, but the top of the mast of Shipwreck D found on Ballard's Black Sea survey suggests that such a design is plausible.[559] Bellabarba notes that in the *Fabrica di Galere*, the mast cap is supposed to be approximately one-fifth of

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[556] Pryor and Jeffreys trace the word to the Classical *karchēsion*, a word "well known to refer to a masthead among other things"; later, it carried over into Latin (*carchesium*) and various medieval words such as *calcet*, or the medieval Latin *calchese*, for a "block mast", or a "mast head with blocks inserted in it for the halyards to be inserted through", an interpretation also supported by John Haldon (Pryor and Jeffreys 2006, 244-45; see also Jal 1848, 385; Haldon 2000a, 281). Haldon speculates based on the etymology of the word that a major part of device may have been fabricated from bronze (Haldon 2000a, 281).
[557] This is only slightly larger than the sheaves found in a Roman period double block from Kenchreae, which were about 12 cm in diameter (Shaw 1967, 390).
[558] Zafiropoulou 1998, 82.
[559] Ward and Ballard 2004, 7-10.

the mast's length.[560] This is a design for a larger and later ship, perhaps including a crow's nest, and therefore may not be suitable for a small Byzantine ship of the ninth century.[561]

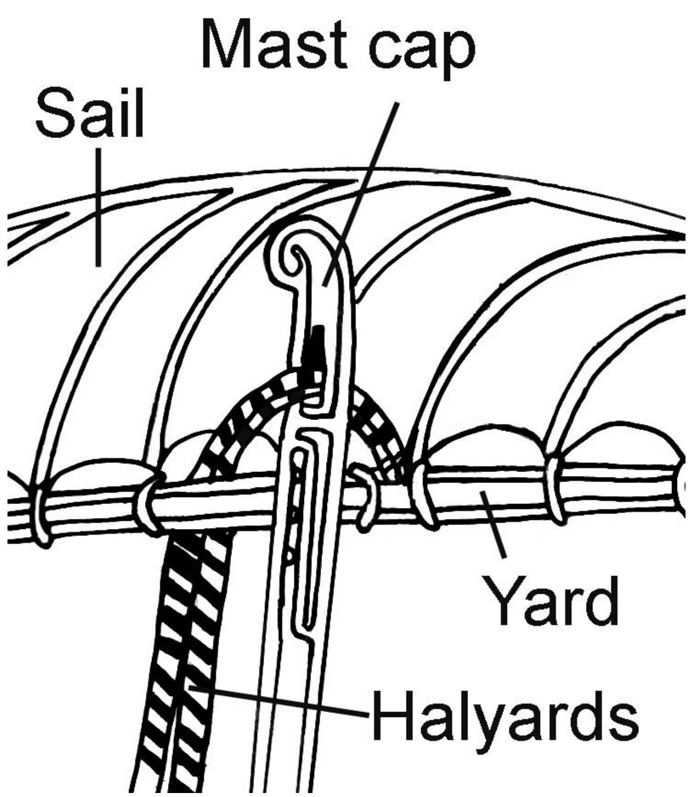

Figure 5.24: Details of the mast head on a lateen-rigged vessel depicted in a twelfth-century mosaic from the Cathedral of Monreale in Sicily. Note the mast cap (*chalkisia* or *calcet*) with a rounded tip, an opening for the halyards (and presumably two sheaves), as well as probable details of mortising and fasteners used to attach the mast cap to the mast (After Zafiropoulou 1998, 82).

[560] Bellabarba 1988, 119-20.
[561] Pryor 1984, 287.

Some representations also show one or a pair of halyard lines running up to the masthead, usually flanking the mast. Later lateen-rigged ships have a pair of sheaves built into the mast cap for a pair of lines used for raising and lowering the lateen yard, or a single sheave for smaller vessels.[562] A dromon depicted in the twelfth-century manuscript of the chronicle of John Skylitzes (Bibliotheca Nacional, Madrid, Vitr 26-2, fol. 34v), shows a masthead with two adjacent vertical lines, probably for a pair of sheaves (**Figure 5.25**).[563]

The shape of the interior of the *chalkisia* is also somewhat speculative. It may have been designed to suspend the ends of the halyard attached to the yard somewhat forward of the sheaves to relieve weight on them, as well as to prevent the halyards and yard from being caught on other rigging lines. This function was assumed in the masthead reconstruction shown in Figure 5.1 and 5.28. However, a number of depictions, including that on the Monreale mosaic, show the halyards attached to the yard exiting the *chalkisia* below the 'beaked' or rounded top of the mast head.[564] The shape of the *chalkisia*, particularly of the more rounded varieties may be intended to keep the yard

[562] Villiers 1961, 254; see also Dimmock 1946, 37; LeBaron Bowen 1949, 112; Lishman 1961, 57; al-Hijji 2001, 79. Howarth (1977, 86) states that two sheaves and halyards are used on dhows because a single halyard would probably be too thick and heavy to be used easily.
[563] Pryor 1995, 105; see also Weismann 1998, 250, 255; Bellabarba and Guerreri 2002, 221, 226, 244. Basch (1991a, 20) also reconstructs rounded Byzantine mastheads in this way.
[564] For other examples, see Martin 2001, 61, Fig. 35; Pryor and Jeffreys 2006, 142, Fig. 8, as well as the Kellia graffito shown in Figure 5.13.

from catching on the mast during tacking and wearing and may have nothing to do with the positioning of the halyard lines.[565]

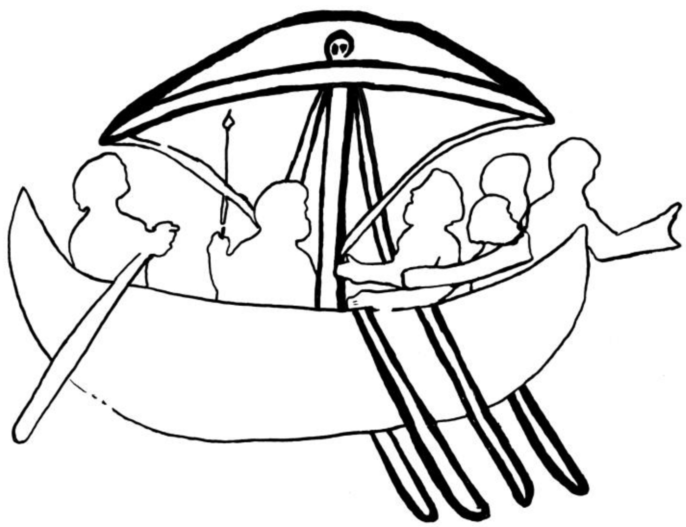

Figure 5.25: A twelfth-century depiction of a Byzantine warship with a *siphon* (Greek fire battery). Note the pair of openings for sheaves in the masthead and the pairs of lines leading up to it, probably representing halyards and shrouds (After Pryor 1995, 105).

The rigging of a lateen vessel is designed to be shifted during a wearing or tacking maneuver. When tacking, a lateen yard must be pulled to the deck on its forward end and maneuvered the upper end around the front of the mast. For this reason, there is no true standing rigging on small lateen-rigged vessels. Forestays are not used, and the main supports for the mast consist of halyards running aft from the mast cap, which supports the yard, one or more shrouds, which are shifted to the lee side when tacking, and a

[565] This interpretation is favored by C. Pulak (personal communication) and could account both for the position of the halyards shown in the vessel shown in Figure 5.20 (supra n. 483 for the alternate interpretation by Martin and Pryor).

parrel fastened with a throat tackle for keeping the yard against the mast. The simplest lateen rig uses only a few lines: the halyard/backstay, the throat tackle/shroud, an additional shroud, two vangs for setting the yard, one or two clews or tacks to secure the lower end of the yard, and a mainsheet to secure the aft corner of the sail. This is the rigging configuration used on the YK 14 reconstruction.

The Halyards

The largest lines of running rigging are the main halyards. These are attached to the yard, run up through the pair of sheaves in the mast head, then down to a pair of double blocks which would probably have been secured to a through-beam in the hull. Another line is run between the halyard triple block and a second triple block at deck level; although this block is usually bolted to a through-beam on Arab dhows, there is no evidence for this configuration in the Byzantine period. It is more likely that a loose halyard block is used, an arrangement shown in some Byzantine ship depictions.[566]

The sizes of blocks used on dhows for the halyards vary with the vessel's size. On large dhows, a pair of lines run to the halyard blocks, while on smaller vessels, a single line is used.[567] The triple block RG 1 found on the Serçe Limanı wreck may have been used as

[566] Al-Hijji 2001, 79. Dimmock (1946, 37) states that the lower halyard tackle is secured to a holdfast on the keel abaft the mainmast. A different arrangement, in which the second block is bolted to the deck, was used on many Arab dhow types; however, these are much more heavily built ships than YK 14 (Lishman 1961, 57; see also al-Hijji 2001, 79). Since no sign of such an arrangement was found in the hull of YK 14, this was not included in the reconstruction. The halyard block size can range from a large double block, as on a *beden* from Oman (Weismann 1998, 248, Fig. 14) to a quadruple block similar to those seen on larger dhows (Jewell 1969, 39, 80, 93).

[567] LeBaron Bowen 1949, 111.

a lower halyard block. As reconstructed, this block was approximately 17-19 cm wide, 10.3 cm thick, and about 35.1 cm long; the block has a hole through the width of the shell at one end for fastening the block to a line, rather than a groove for running a strop around the outside of the block (**Figure 5.26**).[568]

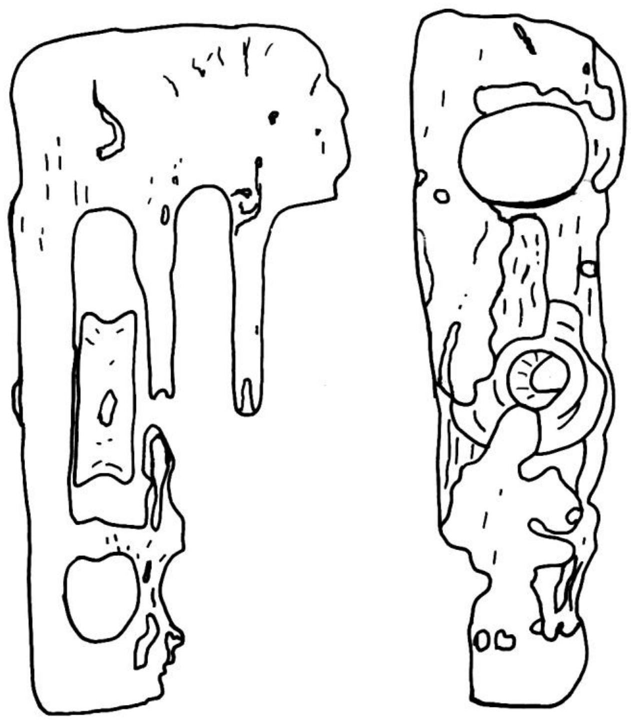

Figure 5.26: Triple block RG 1 from the Serçe Limanı wreck (After Bass et al. 2004, 173).

The reconstructed block of YK 14's rig has two sheaves but is about the same length as the block from Serçe Limanı (34 cm), slightly wider (16 cm), and with a much larger

[568] Bass et al. 2004, 171-73, 178.

sheave, to match the sheave in the mast cap (approximately 16 cm in diameter). The sheaves from the Serçe Limanı wreck are 6-10 cm, similar in size or slightly larger than preserved examples from the INA-excavated shipwrecks at Yenikapı.[569] Larger double and triple blocks were discovered as isolated finds on the site as well.[570]

On the reconstruction, the halyard double block runs to a second double block below it, at or near deck level; the crew would heave on a line running through this block to raise and lower the yard. The two halyards (3 cm in diameter on the reconstruction) run through the sheaves in the mast cap. Each of these are attached to an upper halyard block with two sheaves, which are connected by two additional lines to a lower halyard block, also with two sheaves, secured to a deck beam. The two lines would be belayed on the port and starboard side of the hull on a cleat or through-beam. Both upper and lower halyard blocks are clearly shown in several Byzantine ship representations (Figures 5.10-12). The fact that the Serçe Limanı block is a triple block suggests that it was used for a single halyard rather than a pair as reconstructed on YK 14; several variants are possible.[571]

[569] Bass et al. 2004, 173-77.
[570] See, for example, a well-preserved triple block in Gökçay 2010, 148. Another large double block is about 70 cm long, and has four sheaves of 15-20 cm in diameter mounted in pairs and oriented at 90° angles from each other. The reason for this arrangement is unclear, but a use for raising the yard on a large lateen-rigged vessel is likely (Çölmekçi 2007, 237).
[571] Bass et al. 2004, 178.

The Throat Tackle

The yard is connected to the mast by a large cable run through a heart thimble or block to form a throat tackle. This arrangement is seen on some modern lateen rigs, and a heart thimble that may have been utilized for this purpose was found on the eleventh-century Serçe Limanı ship (**Figure 5.27-8**).[572] This arrangement is intended to keep the yard from swinging too far from the mast. Many different variations on the throat tackle or parrels exist, but it usually consists of a pair of lines run through a deadeye or a heart block around the mast and yard, and then vertically or nearly vertically down from the yard.[573] The throat tackle can be tightened or loosened by pulling on one or the other end of the line. Le Baron Bowen states that the backstay tackle on a small dhow consists of a single moveable block and fall, is made fast aft and to windward, and is used to keep the yard snug against the mast or as a downhaul on the yard if it gets caught against the mast.[574] This line also acts to some extent as a shroud for supporting the mast.[575] The lower end of the throat tackle is tied aft of the mast to a through-beam or cleat.

[572] Bellabarba and Guerreri 2002, 226, 244, 246, 248; see also Bass et al. 2004, 176-77.
[573] See Bellabarba and Guerreri 2002, 246, 248, and Hawkins 1977, 94 for different arrangements of heart blocks for the throat tackle.
[574] Le Baron Bowen 1949, 112-13; see also Dimmock 1946, 39.
[575] Dimmock 1946, 40.

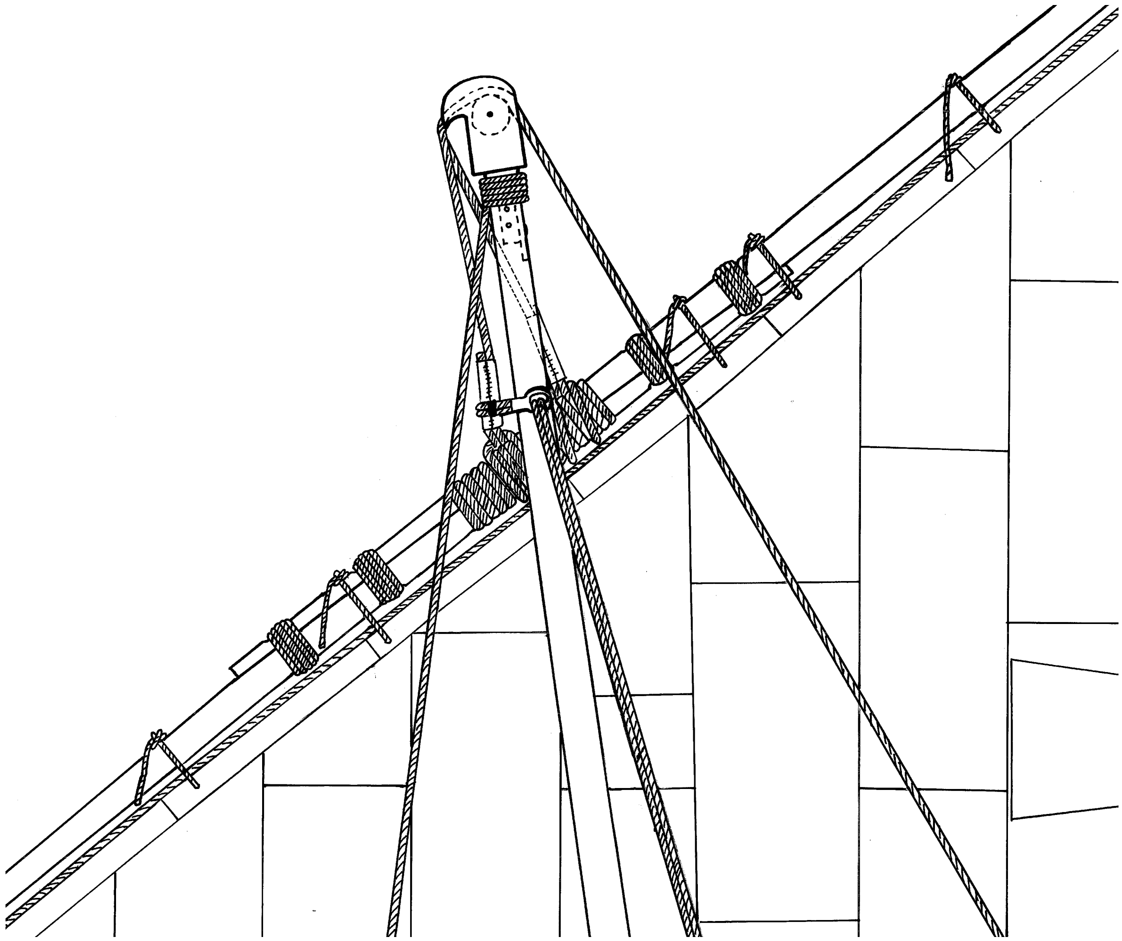

Figure 5.27: Reconstructed masthead of YK 14 based on iconographic evidence of Byzantine ships and modern lateen-rigged craft. Note the robands, halyard lines, throat tackle, and running shroud.

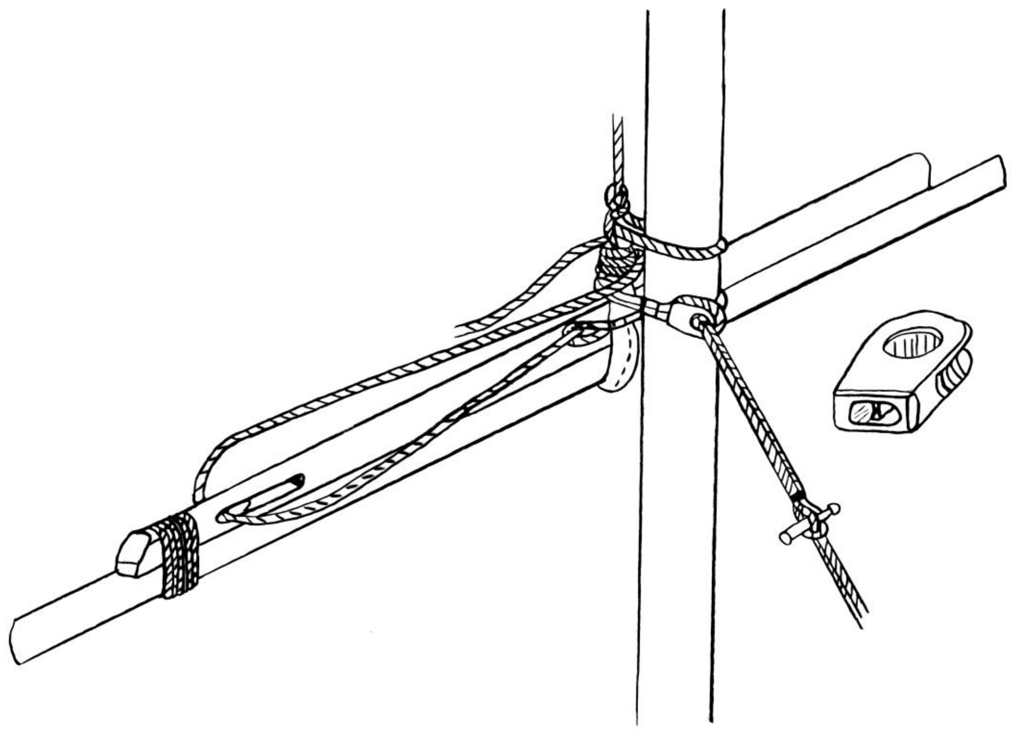

Figure 5.28: Detail of a throat tackle arrangement on a lateen-rigged vessel. Many variations of this basic configuration have been used (After Bellabarba and Guerreri 2002, 248, Fig. 20).

Most of the early medieval artistic representations of single-masted, lateen-rigged vessels show a pair of lines running from the mast head to the deck near the base of the mast. Conceivably one of these lines shown in the artistic representations could be the throat tackle, while another could be a shroud, or, they could be a pair of shrouds, tied to the mast below the mast cap.[576] Parrel beads were used on the throat tackles of many dhows, but are not strictly necessary; no evidence for parrel beads was found on the

[576] The difficulties of interpreting medieval ship iconography are in many cases self-evident and have been noted elsewhere (Adam and Villain-Gandossi 1989, 20; Bass et al. 2004, 179). In many of these cases it is possible that the artist made mistakes in representing the rig of a vessel, or are copying old representations of square-rigged vessels which had since fallen out of use (Polzer 2008, 22).

INA-documented ships from Yenikapı or has been published from any other Byzantine period shipwrecks. The throat tackle was therefore added to the reconstruction without parrel beads; a similar arrangement was found on small dhows and some Italian lateen-rigged vessels.[577] The yard itself is covered with a rope lashing or fender at the mast in order to prevent chafing. Other measures, such as greasing the mast, could also be used for reducing friction, so that the parrel beads would not be strictly necessary.

The Running Shrouds

Lateen-rigged vessels lack standing rigging. The ‘running’ shrouds running from the masthead are removable and shifted every time the vessel tacks or wears to windward; normally, at least two shrouds are attached to windward of the sail, and are shifted to the opposite side if the vessel changes its tack.[578] The shrouds are really only secondary supports. Several authors with sailing experience describe heavy masts of lateen-rigged dhows as able to support their own weight; Dimmock notes that in calm weather, Arab sailors would not even bother to attach the shrouds to avoid the extra effort of shifting them each time the vessel changed its tack.[579] The halyards also act to some extent as backstays, giving the mast additional support.[580] The shrouds were sometimes secured or tightened with deadeyes or blocks in later periods; deadeyes were used on square rigs in the Roman period, but do not appear in Middle Byzantine period ship iconography.[581]

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[577] Bellabarba and Guerreri 2002, 226, 244, 246, 248, 250-51; see also Howarth 1977, 47.
[578] Le Baron Bowen 1949, 114; see also Dimmock 1946, 39; Pryor 1994, 67.
[579] Dimmock 1946, 40-1; see also LeBaron Bowen 1949, 114; Howarth 1977, 86, 89, 110; Villiers 2006, 33.
[580] Villiers 2006, 33; see also LeBaron Bowen 1949, 114.
[581] Whitewright 2007, 284.

Several researchers of lateen rigs used in modern times comment on the use of toggles in dhow rigs as quick-release devices for the lower ends of the shrouds.[582] This is a likely explanation for the presence of numerous rigging toggles found on the Yenikapı shipwrecks and across the site.[583] These toggles tend to be of two sizes: a small size, about 11-15 cm long and 2-3 cm in diameter at the center, and a larger size, about 20-25 cm long and also 2-3 cm in diameter.[584] Although rigging toggles from the Yenikapı ships were usually carved, some examples were finely lathe-turned as well; they were usually made from oak or boxwood.[585] Polzer refers to this type as 'straight or conventional' toggles, to differentiate them from bobbin-shaped toggles used in Classical period square rigs; he notes that 'conventional' toggles are usually found in two varieties—with or without knobs on their ends.[586] Both types of 'conventional' toggles were found at Yenikapı, as well as on the early ninth-century Tantura Wreck B, the eleventh-century Serçe Limanı wreck, and many other ancient and medieval shipwrecks and submerged sites.[587] On Arab dhows, toggles very similar to examples from the Yenikapı and Tantura shipwrecks were used at times to secure the mainsheet to

[582] Hawkins 1977, 94; see also Le Baron Bowen (1949, 114) and Bellabarba and Guerreri (2002, 221, 247) and for other instances of the modern use of such toggles.
[583] One unexplained feature of YK 1 was several nearly vertical holes drilled in the wales on the outside of the ship. These were found plugged with caulking and/or wooden plugs; there was little or no wear around their edges. Polzer (2008, 24, Fig. 23) notes the use of holes in the wale of a fourteenth-century cog depicted in the Luttrell Psalter (c. 1325-1335) as securing points for running and standing rigging, held in place with toggles. A similar use could be hypothesized for the holes in the wales of YK 1, although they are quite small (approximately 2 cm in diameter); similar features on YK 14 were used to secure through-beams to the wale rather than for a rigging function, and no such features were found on the preserved wale on YK 5.
[584] Çölmekçi 2007, 237, cat. N. Y76; see also Gökçay 2010, 150.
[585] See Gökçay 2010, 150, for an example of a lathe-turned toggle with knobs at its ends from Yenikapı. One complete and one partially-preserved lathe-turned toggle were found on YK 11 (R. Ingram, personal communication).
[586] Polzer 2008, 238.
[587] Bass et al. 2004, 177. Polzer (2008) provides a detailed catalog and discussion of toggle finds.

the sail, a feature included in the reconstruction.[588] The larger type of toggle found at Yenikapı was used as a standard size for all toggles on the reconstruction, having a maximum diameter of about 3 cm and a length of 20 cm, although the smaller-sized toggles could have been substituted for some of the same functions.

The Sail, Vangs, and Mainsheet

The remaining components of the rig are several lines used for handling the yard and the sail itself once they are aloft. The proportions of the lateen sail used in the reconstruction are based on one formula used by Kuwaiti dhow builders, where the head of the sail is 1.25 times the length of the foot of the sail.[589] Similar proportions were used by Venetian shipbuilders in the fourteenth and fifteenth centuries.[590] Textual evidence indicates that linen and hemp (sometimes combined in the same cloth) were the most common sources of sail material in the ancient world, although cotton was also used in some areas; leather or extra layers of sail material were used for reinforcement in areas prone to chafing, and a boltrope was sewn into the outer edge of the sail for the attachment of running rigging.[591]

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[588] Le Baron Bowen 1949, 114.

[589] Al-Hijji 2001, 87-90. Several other proportions were used for sails of different shapes, or the whole process could be done by eye.

[590] Bellabarba 1988, 123-27.

[591] Black and Samuel 1991, 220, 222; see also Haldon 2000a, 284. Black and Samuel (1991, 219-20) also note instances of the use of reeds, matting, wool (see also Cook et al. 2002, for medieval Viking sails), and leather for sails. Finds of sails are rare in archaeological contexts, but fragments of ancient sails of cotton and linen dating to the Hellenistic and Roman periods have been found on several sites in Egypt on the Red Sea coast (see Wild and Wild 2001; Whitewright 2007). Cotton was not unknown in the medieval Mediterranean-- its cultivation occurred in Egypt by the third century B.C.E., and it sometimes appears in Byzantine sources as a material for clothing, but cotton was probably unusual for use in sail cloth outside of the Indian Ocean and Red Sea (Black and Samuel 1991, 222; see also Wild and Wild 2001, 211-20;

As in later periods, sails in the Byzantine period were made from long strips of sail cloth (see Figures 5.13, 16-8). This style of sail manufacture was determined by the width of the hand-looms in use.[592] The cloth strips used on the YK 14 sail reconstruction are 64 cm wide, or approximately two Byzantine feet, which is also very close to the widths of sail cloths mentioned in documents from later periods.[593] In some regions, sail cloths were sewn to overlap slightly more towards the head than towards the foot in order to make a more billowing sail, but for the sake of simplicity, the sail cloth strips are reconstructed as running perpendicular to the top of the keel, without any major or obvious overlap.[594] This follows the practice on dhow sails, where the seams are "absolutely vertical," according to Alan Villiers; Le Baron Bowen and Dimmock (1946) who also note the bagginess of these sails.[595] This appears to be shown on sails in several Byzantine and medieval ship depictions, where the sail billows out slightly at the yard between the points where the sails is secured to the yard.

As in later periods, the sail would likely have reinforcement bands along its edges, a feature found on the remnants of Roman period sails excavated from harbor sites along

289; Agius 2008, 163). Boltropes for sails are mentioned in the naval inventories for the Cretan expeditions in the *Book of Ceremonies* (Haldon 2000a, 284).

592 See, for example, Lever 1998, 55, Fig. 312-15; al-Hijji 2001, 88.

593 The Royal Navy used sail cloths 24 inches (60.96 cm) wide in the late eighteenth century (Gill 1982, 62). Weismann's ethnographic study of an Omani beden *Al-Khammam*, a single-masted, settee-rigged cargo vessel approximately 15 m long, had a sail made from 30 lengths of cloth having a width of about 61 cm each, made for a yard about 22 m long (1998, 246, 251, 255).

594 Bellabarba (1988, 125) notes its occurrence in the instructions for manufacturing lateen mizzen sails in *Fabrica di Galere*. See Gill 1982, 67, for a 1794 reference to cutting sails with a 'hollow'.

595 Le Baron Bowen 1949, 118; see also Dimmock 1946, 35.

the Red Sea.[596] There is no reason to believe that the basic sail features seen in the nineteenth century are much different from medieval sails: a bolt rope with clews, earrings, and cringles for the attachment of rigging lines would have run around the outer edge of the sail where appropriate. No reef points were added to the sail in the reconstruction, although it is possible they were used based on their presence on sails in the Kelenderis mosaic.[597]

On Arab dhows, robands, "like reef points," are run through grommets in the sail and tied to the yard.[598] These robands are easier to remove than other arrangements (for example, running a single rope through all of the grommets in the sail). This is an important consideration in a lateen rig, since shortening sail involves lowering the yard, removing the sail, and attaching a smaller sail.[599] This practice seems to have existed as early as the fifth century, based on the bishop Synesius' account of a voyage on what was probably a lateen-rigged vessel.[600] For this reason, dhows carry two to four sets of sails.[601] The ability to remove a sail from the yard quickly is, therefore, a high priority on a lateen-rigged vessel, and the use of these robands is a fairly practical solution. Many ships in this period probably carried different sails of several sizes, to be used in

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[596] Bellabarba (1988, 122-25) notes that such reinforcements are described on fourteenth-century square sails in *Fabrica di Galere*; similar reinforcements were used on sails into modern times (see Lever 1998, 55-6, 60). The staysails in Lever (1998, 60-1) were used as basic guides for the YK 14 sail reconstruction. Steel (1982, 68-9) also describes and illustrates reinforcement bands on the edges of sails.
[597] Friedman and Zoroğlu 2006, 111, 115.
[598] Dimmock 1946, 37; see also Le Baron Bowen 1949, 115; Al-Hijji 2001, 90-1; Bellabarba and Guerreri 2002, 254.
[599] Le Baron Bowen 1949, 115, see also Dimmock 1946, 39; Hourani 1995, 100. Le Baron Bowen (1949, 115-16) notes that bonnets were sometimes used on dhows.
[600] Casson 1952; 1966, 50-1.
[601] Dimmock 1946, 37; see also Le Baron Bowen 1949, 116; Weismann 1998, 246; Al-Hijji 2001, 86-90.

different weather conditions, as well as spare sails; however, on YK 14, which was probably a small coastal vessel intended to be operated cheaply, the crew and owners could perhaps have dispensed with such extra equipment. In the 949 Cretan naval expedition inventory in the *Book of Ceremonies*, dromons are equipped with multiple sails, while only single sails were provided for auxiliary light galleys (nine *karabia* and two *mōneria*, or light galleys) used for transporting Rus and prisoners.[602]

Vangs are also necessary for manipulating the upper end or peak of the yard. These are shown in many Byzantine ship representations, often with blocks in place (See **Figures 5.16-17, 5.29**). Usually these lines are left slack, but are tightened to steady the yard when sailing to windward and to keep the yard from swinging when sailing downwind.[603] The mainsheet is belayed to a cleat on the stern deck on the leeward side, the practice on Arab dhows (unless they are sailing close-hauled); sometimes this is secured with a toggle on dhows, a feature incorporated into the reconstruction.[604]

Another set of clews or tacks are also used to control the forward end of the yard. The arrangement for the clews is again based on the ship in the St. Gregory of Nazianzos manuscript, in this case a miniature depicting the story of Jonah, a pair of clews are run through blocks at the peak and the foot of the yard (see Figure 5.16). This is very similar to a rig shown for a lateen mizzen mast in Darcy Lever's 1819 rigging manual, with the

[602] Haldon 2000a, 228-30; see also Pryor and Jeffreys 2006, 190.
[603] Le Baron Bowen 1949, 114. Dimmock (1946, 38) calls these 'peak' and 'butt braces.'
[604] Le Baron Bowen 1949, 113; see also Dimmock 1946, 39.

exception that a simpler gun tackle purchase is used instead of a luff tackle.[605] This is a more complex arrangement than that seen on most other Byzantine representations, which usually show a block at the upper end only (e.g., **Figure 5.29**). One pair of vangs ran from the sail to each side of the hull; presumably only one would be taut at any given time. The vangs would be secured to cleats on the bulwarks of the hull. The blocks used on the vangs on the reconstruction are based on a type of small single block found at Yenikapı.[606]

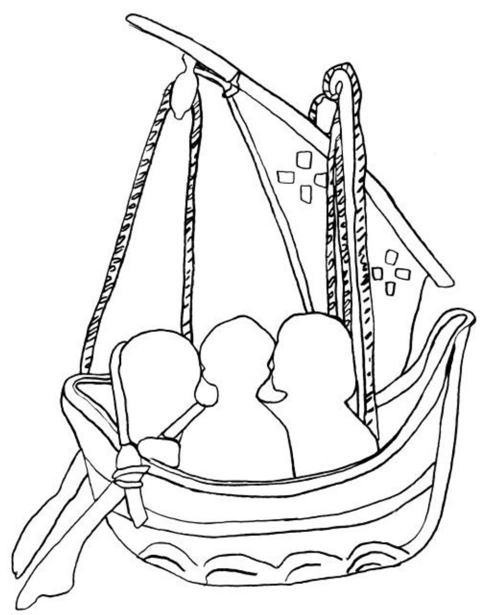

Figure 5.29: A Byzantine vessel with a block used for the vang. From an 11th-12th century manuscript (Cod. 14. f. 52r) from the Esphigmenou Monastery, Mt. Athos (After Zafiropoulou 1998, 84).

A variety of timbers could have served as cleats on the hulls of Byzantine ships. These seem to consist of two types, both found on YK 1 at Yenikapı. One type is a large

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605 Lever 1998, 42.

606 Çölmekçi 2007, 238. A similar block was also found on YK 11.

horizontal timber, probably added during the refit of the hull (**Figure 5.30**). Notches cut into the timber's outer face could perhaps have been used for securing lines.

Figure 5.30: Possible cleat on YK 1. Note the notches cut into the outboard side of the timber (facing downward in the photograph).

Other features on the same ship may have served as cleats or locations for belaying rigging lines. Square mortises were cut through the forward and aft faces of three futtocks at their upper ends; a wooden peg was driven through one of the holes at futtock F 16 (**Figure 5.31**).[607] An identical design was used for a cleat or belaying pin on the

[607] The mortise with the peg driven through it was found on futtock F 16, a 'secondary' futtock installed after the overhaul of the ship. The two other mortises are in futtocks F 17 and F 24, which are 'primary'

deck of Shipwreck D found in the Black Sea.[608] On Arab dhows, Lishman describes "rope grommets fitted at convenient points round the vessel" through which a toggle for the shrouds can be passed.[609] Another simple option would be to belay lines to through-beams in the hull.[610]

Figure 5.31: Futtock timber from YK 1 with a large peg driven through a fore-and-aft-oriented hole in the upper end of the timber. This feature may have been used as a cleat or belaying pin.

futtocks installed in the ship during its initial construction. It is likely that the raising of the sides of the ship would have required changes in the locations of cleats or belaying points for rigging lines.

608 Ballard et al. 2001, 619-21; Ward and Ballard 2004, 10.

609 Lishman 1961, 57.

610 Villiers (1962, 113) comments on the "lack of belaying-pins [or] proper seamanlike appurtenances for the belaying of anything" on Arab dhows. Dimmock (1946, 40) states that "cleats are unknown" but mentions the use of belaying pins to secure the shrouds, while LeBaron Bowen (1949, 113, Fig. 13) notes the use of half-cleats at the edge of the poop deck to loosely secure the sheets, or the use of a toggle for the same purpose (113-14, Fig. 14).

6) Conclusion

In spite of the poor preservation of YK 14's upper hull and the almost complete absence of rigging material, a plausible reconstruction of the ship's rig can be made based on other sources, including archaeological remains of other Byzantine ships, ship depictions in Roman and medieval art, and ethnographic sources on more recent lateen-rigged vessels. The mechanics of a lateen rig are well understood, and the hull remains point to a limited range of possible rigging arrangements. The major problems in the reconstruction involve the size and cant of the mast and yard; these drastically affect the sailing qualities of a ship, and there is little or no contemporary information on the dimensions of these parts. The other main difficulty in the reconstruction was the interior of the vessel, including the size of the decked area and the dimensions of the quarter rudders and their mountings. These features must remain largely conjectural, but could be determined with more accuracy from new archaeological finds or research into the sailing performance of the reconstructed hull.

CHAPTER VI

TIMBER AND OTHER MATERIALS USED IN THE CONSTRUCTION OF YENİKAPI 14 AND THE POSSIBLE ORIGIN OF THE SHIP

The timber, pitch, and other materials used in the hull of YK 14 provide valuable evidence for economic and environmental factors affecting the ship's construction. The natural distribution of tree species used in the construction of the ship as well as the advantages and disadvantages of using each species are especially revealing. For example, it is unlikely that the best quality materials would be used on all ships; only timbers of certain species and sizes would have been available in a specific region. Local availability and consequent low cost of timbers must have influenced selection in many instances, especially in cases such as YK 14 in which specific timber types were used in spite of some undesirable characteristics. Based on these factors, the timbers, and other materials used in YK 14's construction and operation suggest a local origin for the ship.

1) Timber Selection, Mechanical Properties, and Origin of the Ship

The timber used for the construction of the hull would have been carefully selected by a master shipwright. Many of the planks could have been cut from straight trunks (as well as shorter, more irregular pieces, judging from some of the hull planks used in the ship). Relatively young trees with small diameters were used for the construction of most of the Yenikapı ships, possibly due to their superior mechanical properties in comparison to older timbers.[611] Exploitation of local forests could have also exhausted the supply of older, larger trees, forcing local shipwrights to rely on younger trees for shipbuilding timber.[612] This is particularly likely if the ship was built in the immediate environs of Constantinople, which would have required vast amounts of timber and wood for architectural uses as well as fuel. YK 14’s frames in particular seem to be small even by the standards of other vessels from the site (see Chapter VII).

The construction of a ship’s hull would have required the felling of straight logs, to be sawn into planks for the hull, while compass timbers, used for the curved members of the hull such as the frames, would have been selected as tree limbs from individual

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[611] Liphschitz and Pulak 2009, 170. According to Nicolaes Witsen, the seventeenth-century chronicler of Dutch shipbuilding methods, ”This can be taken for a general rule, that one does not choose wood of the largest size for shipbuilding, because large trees are old trees, and old trees are like old people, weak and brittle” (Hoving 2012, 23).

[612] Rackham (1982, 208-9) observes that medieval structures in England were usually built of “large numbers of small oaks. Every timber, large or small, is made from the smallest tree that will serve the purpose.” Waney surfaces (i.e., surfaces with only the bark removed) are usually left on these timbers. Such oaks were typically 5-24 inches in basal diameter (12.7- 60.96 cm), about 20 ft (6.1 m) long, and felled after 25-80 years of growth. Rackham notes that most of these oaks are probably the products of managed forest lands; perhaps similar practices affected the supply of oak timbers used for the construction of the Yenikapı ships as well (Rackham 1982, 203-9).

trees.[613] Ancient authors and shipbuilding treatises from later periods recommend that trees be felled from the late summer to winter, in order to minimize the amount of moisture in the form of sap in the wood.[614] After felling, timber was usually seasoned for a period of time.[615] According to Theophrastus and Vegetius, green timber could also be used for shipbuilding, as it is easier to bend and work, an advantage for installing hull planks and wales on a ship. Since green timber is prone to shrinkage, splitting, and damage from rot, however, seasoning timber before use may have been preferred, with the length of seasoning time dependent on the species of wood and local conditions.[616] Seasoning wood by air-drying was the most common technique, but ancient authors mention a variety of other methods, including the burying of the timbers in dung, grain, earth, or beach sand, or immersion in seawater.[617] Although the last two methods listed were apparently used for ship timbers, most of these methods seem to have been intended for structural timbers in buildings, which may have been different from those used for shipbuilding timber. The extent to which timbers for shipbuilding were

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[613] Rival 1991, 113-14.

[614] Veg. *Mil*. IV. 36; see also Theophr. *Hist. Pl.* V. I. 1-3; Vitr., *De arch.* II. IX. 1; Smith 1993, 56; Hoving 2012, 23.

[615] Seasoning of felled oaks for one to three years was the practice in Iberian shipbuilding in the sixteenth and seventeenth centuries (Smith 1993, 55-6).

[616] Theophrastus states that excessively dry wood is difficult to work and therefore also undesirable (Theophr. *Hist. Pl.* V. VI. 3; see also Veg. *Mil.* IV.36; Ulrich 2007, 329-30). Statements of ancient authors on the properties of green and seasoned wood are confirmed in later sources as well; see, for example, Smith 1993, 78; and Hoving 2012, 23. Hanson (1978, 295-96) believes that the importance of seasoning structural timbers may be exaggerated by modern scholars. He notes that green timber was frequently used in building construction in the Middle Ages, and that seasoning is desirable in building timber mainly to create a moisture content in the timber that is "approximately midway between the anticipated extremes it is likely to experience;" failure to achieve this state is what causes warping and cracking. Modern reconstructions of Anglo-Saxon buildings in West Stow (Suffolk, England) were built of unseasoned oak felled within two years of construction; the timbers were easily worked throughout this period, although joints would sometimes require re-cutting if timbers were left to season for longer periods (Darrah 1982, 219, 222).

[617] Commentary by ancient sources on seasoning wood are summarized in Ulrich (2007, 261-62).

seasoned probably cannot be determined, but some seasoning of the timbers used hull is likely.[618]

Unfortunately, any attempts to determine the origins of the ship based on the wood types used in its construction must be tentative. Four species of trees were used for the major components in the hull of YK 14—Turkey oak (*Quercus cerris*), Sessile oak (*Quercus petraea*), European ash (*Fraxinus excelsior*), Sycamore maple (*Acer pseudoplatanus*) —all of which are native to Turkey or the coasts of the Aegean and Black Seas today (**Figure 6.1; Table 6.1**). The present ranges of these species overlap in the Sea of Marmara and southwestern Black Sea regions. In later periods, shipbuilding centers were usually located near major forests, and shipbuilders would often travel to the timber sources to build ships rather than pay the expense of importing timber great distances to the construction sites.[619]

[618] Vitruvius notes that oak remains well preserved when buried, but will warp and crack when exposed to moisture; this is especially the case with Turkey oak (*Q. cerris*), which, he notes, will "soon decay" when exposed to moisture (Vitr., *De arch.* II. IX. 8-9).
[619] Meiggs 1998, 357-58, 393-94; see also Imber 1980, 213, 220-21, 227-30, 235-39, 242-45, 247; Braudel 1995:1, 140-43; Tabak 2008, 191-92, 273.

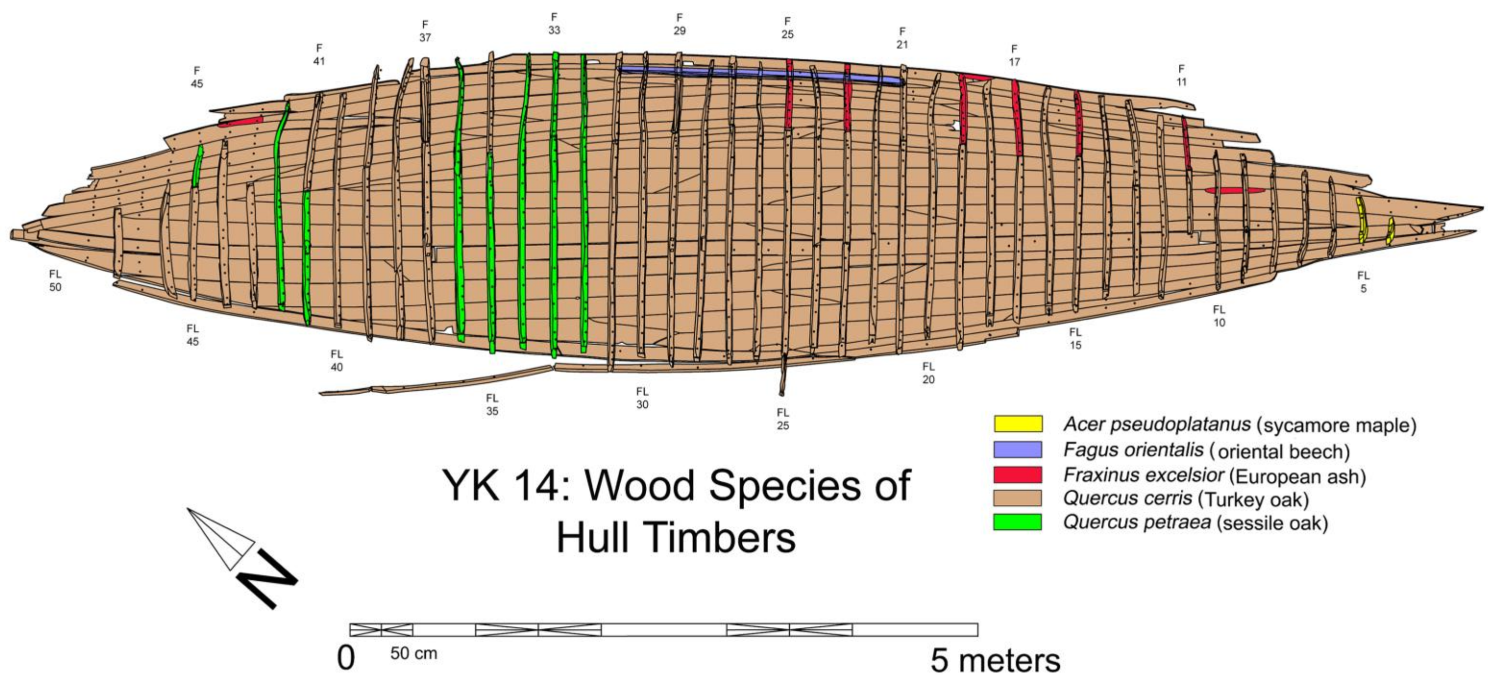

Figure 6.1: Wood species used in the construction of YK 14.

Table 6.1: Timber Types Used in the Hull of Yenikapı Wreck 14

Wood Species:	Common Name:	Component:	Range:
Acer pseudoplatanus	Sycamore or sycamore maple	Frames Hull planks Treenails Coaks	Most of Europe, Caucasia, Thrace (Davis 1967:2: 501, 511)
Fraxinus excelsior	European ash/common ash	Futtocks	Most of Europe/southwestern Asia and northern Anatolia (Davis 1978:6: 149-51)
Quercus cerris	Turkey oak	Frames Hull planking Keel timbers Treenails Coaks	Southern Europe/all of Anatolia except for the northeast and east; Syria and Lebanon (Davis 1982:7: 674-6)
Quercus petraea	Sessile oak	Frames Hull planks	Most of Europe, Balkans, northwest Anatolia (Davis 1982:7: 667-8)
Rhamnus alaternus	Italian buckthorn	One sampled coak	Mediterranean region, Black Sea coast of Anatolia, Crimea (Davis 1967:2: 526, 531)
Ulmus campestris	English elm	3 coaks	Western Turkey, Thrace, and the Aegean islands (Davis 1982:7: 647)
Phillyrea latifolia	Mock privet	9 sampled coaks	(Davis 1978:6, 153, 157-8)
Buxus sempervirens	European boxwood	Sheave fragment (UM 23)	Outer Anatolia, west central, and southern Europe (Davis 1982:7, 630-2, 887)
Fagus orientalis	Oriental beech	Toggle (UM 24); one coak	Most common along northern coast of Anatolia; also found in northwestern and southern Anatolia (Davis 1982:7, 657-8, 887)

Some documentary evidence for timber trade in the Byzantine period survives, but most references concern the procurement of timber for the Umayyad and Abbasid caliphate, particularly for the construction of warships. Timber was shipped to Egypt by Byzantine and Venetian merchants, and in the seventh century, Arab fleets visited the southern coast of Anatolia with the express purpose of felling timber for ships.[620] This trade, along with the export of arms to the Caliphate, may have been significant, based on intermittent attempts by Byzantine emperors in the ninth and tenth centuries to ban it.[621] ‘Franks,’ or Christians who were either Byzantines or western Christians such as Italians, were a regular presence in Fatimid territory in the tenth century and later; these travelers were often merchants.[622] Such trade could account for the wood types used in the construction of the Tantura ships discovered off the coast of Israel, which were built with species widely available in Anatolia and Cyprus, but several of these wood species, such as Turkish pine (*Pinus brutia*) and Mediterranean cypress (*Cupressus sempervirens*), appear to be relatively rare on the Yenikapı site. In the Aegean, the monks of Mt. Athos exported timber and pitch in the mid-eleventh century, a trade later banned by Constantine IX (1042-1055), and in subsequent periods forests in the North Aegean and the Black Sea were major sources of shipbuilding timber for Ottoman naval arsenals.[623]

[620] Jacoby 2009, 381-82; see also Stratos 1980, 232-33, 238-39.
[621] Lopez and Raymond 2001, 333-35; see also Dunn 1992, 263; Jacoby 2000b, 35-6.
[622] Jacoby 2009, 372-73.
[623] Dunn 1992, 263.

In the case of YK 14, wood species used in the ship's construction seem to be unusual choices for long-distance export. Some timbers are high-quality hardwoods, such as Sessile oak, (*Quercus petraea*), a member of the white oak group, and European ash (*Fraxinus excelsior*), both used for frames in the hull. However, YK 14, as well as a number of other roundships from Yenikapı, was built predominantly of Turkey oak (*Quercus cerris*) (see Chapter VII).[624] This choice contrasts with wood types seen on many earlier Mediterranean shipwrecks as well as with ancient textual references to timber types preferred for shipbuilding: softwoods such as pine were more commonly used, although oak was used for keels so that they could better withstand frequent beaching, and other hardwoods were used for hull components that were especially prone to wear.[625]

Theophrastus comments on the strength of Turkey oak (*Q. cerris*) when it is cut lengthways,[626] as well as the conditions in which oak has a tendency to decay:

> Again, whether a given wood is not liable to decay may depend on the purpose to which it is put and the conditions to which it is subjected: thus the elm does not decay if exposed to air, nor the oak if it is buried or soaked in water; for it appears to be entirely proof against decay: wherefore they build vessels of it for

[624] YK 1, 5, 23 and 24 were built entirely of Turkey oak, with timbers from other species added to YK 1 only in a later overhaul phase (Liphschitz and Pulak 2009, 166-8). A variety of wood species were used in the construction of YK 12: Akkemik (2008, 203-11) identifies hull components as oak (*Quercus*), primarily of the white oak group, ash (*Fraxinus*), chestnut (*Castanea sativa*), common walnut (*Juglans regia*), hornbeam or Oriental hornbeam (*Carpinus betulus* or *orientalis*), and Oriental plane (*Platanus orientalis*). He states that all could have been obtained in nearby forests, with the possible exception of Common Walnut, which grows naturally in eastern Turkey but is cultivated throughout the country (Akkemik 2008, 203-11).
[625] Steffy 1994, 54, 258; see also Theophr., *Hist. Pl.* V. VII. 1-3; Veg., *Mil.*, IV. 34.
[626] "The *aigilops* (Turkey oak) is the straightest growing and also the tallest and smoothest, and its wood, cut lengthways, is the strongest" (Theophr. *Hist. Pl.* III. VIII. 3-4).

> use on rivers and on lakes, but in seawater it rots, though other woods last all the better; which is natural, as they become seasoned with the brine.[627]

Turkey oak (*Q. cerris*) is also more porous and susceptible to rot than white oaks such as English oak (*Quercus robur*) and Sessile oak (*Q. petraea*), which were regarded as excellent shipbuilding timber in later centuries.[628] This difference seems to have been recognized in ancient times—Vitruvius describes Turkey oak as susceptible to rot—and is also noted in later Italian shipbuilding contracts, which sometimes specify that ships are not to be built from Turkey oak.[629] The abundant pitch on YK 14's hull may have been applied in part to protect the Turkey oak timbers, which were prone to shrinkage and splitting, from further leakage.[630]

The choice of Turkey oak as the main construction timber for YK 14 and other roundships from Yenikapı was probably due in large part to its mechanical properties, but also to its local availability and affordability as well.[631] Steffy notes that Turkey oak is a widely used shipbuilding timber in many periods of Mediterranean history, particularly for tenons in mortise-and-tenon joints (along with Kermes oak, *Quercus*

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[627] Theophr. *Hist. Pl.* V.IV.2-4 (trans. Hort 1916). Theophrastus' observations on the decay of oak vessels in seawater may be relevant to the rot seen in the hull of YK 14. Certain species of bacteria attack waterlogged wood in fresh- and saltwater; perhaps bacteria of a specific type preferentially attack oak in saltwater (Schweingruber 2007, 245).
[628] Steffy 1994, 258; see also Rival 1991, 53; Liphschitz and Pulak 2009, 169-70.
[629] Liphschitz and Pulak 2009, 170; see also Beltrame 2009, 253-4. Vitr., *De Arch*. II. 9.9. Turkey oak's susceptibility to rot is also implied in a passage in Pliny's *Natural History* (XVI.VIII.22).
[630] Liphschitz and Pulak 2009, 170.
[631] Liphschitz and Pulak 2009, 167-68, 170. Much of the best timber was likely reserved for the imperial fleet. The imperial government imposed tax obligations on well-forested coastal provinces that included the felling and transportation of timber, the production of sawn planks and pitch, and the construction of complete vessels (Dunn 1992, 262-72). See also Haldon (2000a, 218, 286-88) and Oikonomides (2002, 1000) for the procurement of timber and other naval supplies for the Byzantine navy.

coccifera), due to the timber's strength and resistance to shear.[632] It was used almost exclusively for treenails on YK 14 (504 of 507 treenails sampled from the ship are identified as Turkey oak) and several other Yenikapı ships, for the same reason.[633] The treenails used in YK 14 were often cut from branches, perhaps from the trees that supplied the oak timbers for the hull; both the treenails and the larger oak timbers could have been cut at approximately the same time.[634]

A wider variety of wood species were used for the ships' coaks. Some are from species used for some hull timbers, such as Sycamore maple (*Acer pseudoplatanus*) and European elm (*Fraxinus excelsior*), while others were not used elsewhere in the hull. For example, mock privet (*Phillyrea latifolia*) is a shrub found throughout Mediterranean and Black Sea coasts, often in oak forests.[635] Italian buckthorn (*Rhamnus alaternus*) is another shrub widespread in both the Mediterranean and Black Sea regions.[636] Although these shrubs are too small to provide many large hull timbers, they were sufficient for producing hull fasteners. It seems likely that these species were locally available near the construction site of the vessel and were used for this reason.

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[632] Steffy 1994, 258.
[633] Liphschitz and Pulak 2009, 167-70. Turkey oak was by far the most common wood type for treenails on both the roundships and galleys, although about a quarter of the treenails from the galley YK 2 were from other species, primarily elm (*Ulmus campestris*). YK 11 was built without treenails, but the tenons were made from oak, primarily Kermes Oak (*Quercus coccifera*).
[634] Later shipbuilding treatises note the importance of using well-cured treenails, since green treenails will rot (Hoving 2012, 23; see also Smith 1993, 79; R. Blake (1845) in Bruzelius 2010).
[635] Davis 1978:6, 153, 157-58.
[636] Davis 1967:2, 526, 531.

Unfortunately, because the wood types used in the construction of YK 14 are fairly common in the eastern Mediterranean and Black Sea regions, the location of the ship's construction cannot be conclusively established. It is possible that even timber of lower quality was sometimes transported over long distances in this period, so the importation of timber to a construction site cannot be completely ruled out.[637] The environmental history of the Sea of Marmara region in the Byzantine period is still poorly known, but historical references to forests and timber procurement in the region from later periods, there were significant timber sources until at least the seventeenth century.[638] Turkey oak is a widespread species in Anatolia, but the distribution of species such as Sessile oak (*Q. petraea*), European elm (*Ulmus campestris*), and European ash (*F. excelsior*), seems to be concentrated in Thrace, and the northwest and Black Sea coasts of Anatolia rather than the warmer, more southerly regions of the Aegean and Anatolia.[639] It is very likely that they were obtained in the immediate vicinity of Constantinople or somewhere along the coast of the Sea of Marmara.[640]

2) Waterproofing Materials

Well-preserved samples of caulking from the planking seams and the original pitch coating of the hull were recovered from the YK 14 shipwreck. The caulking material consisted of a fibrous filler material, in this case grass, and a binding or waterproofing

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[637] Dunn 1992, 258-59; Laiou and Morrisson 2007, 64.

[638] Dunn 1992, 240-50; see also Meiggs 1998, 357-58, 393-94. The arsenal of the Ottoman fleet in Istanbul in the sixteenth and early seventeenth centuries had access to abundant timber from the Gulf of Izmit, the coast of Bithynia/Kocaeli, and the Black Sea coast (Imber 1980, 228-30; see also Inalcık 1996, 463, 465).

[639] Davis 1967.2: 511, 515; 1978.6: 149-151; 1982.7: 647, 886-89.

[640] Liphschitz and Pulak 2009, 166; see also Akkemik 2008, 211.

mixture, which appears to be identical to the light brown or yellow waterproofing material used on both the inside and the outside of the ship's hull.

Although caulking materials from the Yenikapı shipwrecks have not been fully analyzed, they are similar in appearance to the materials used on the other shipwrecks at Yenikapı. Liphschitz confirmed that a caulking sample from YK 1, a late tenth- or early-eleventh century C.E. wreck was made from the *Poaceae* (grass) family; all eight shipwrecks excavated by INA at Yenikapı used caulking material with a similar appearance.[641] Due to the difficulties involved in identifying grass fragments based on microscopic structure or phytoliths, it is difficult to identify the material more specifically.[642] Pollen extracted from caulking samples from the ship also consisted predominantly of grass pollen, mixed with small amounts of other types, primarily those of deciduous tree species.[643] A wide variety of bulking fibers were used in plank seam caulking in ancient and medieval Europe, including grasses, hemp, flax fibers (an item listed for use as caulking on tenth-century dromons in the *Book of Ceremonies*), moss, animal hair, and cloth.[644] These would be combined with a waterproofing agent such as pine pitch or pine tar. Sometimes substances such as beeswax or tallow were also

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[641] Caulking fibers identified as a grass species were also found in plank seams on the Byzantine Serçe Limanı ship (Bass et al. 2004, 112, 313).
[642] Grass structures are highly homogenous, and silica phytoliths in grass are generally not sufficiently distinctive to be distinguished by species, but they can be distinguished by 'tribes'; a type collection of Mediterranean grasses would be required to pursue this option for identification thoroughly (Piperno 1988, 19-43, 255-57; see also Tsartidou et al. 2007). Some common fiber materials that may have been used for caulking, such as flax, produce no phytoliths at all (Catling and Grayson 1982, 16).
[643] Pollen was extracted from three caulking samples from YK 14 by the author under the guidance of Vaughn Bryant of the Texas A&M University Palynology Laboratory.
[644] Bockius 2006a, 118; see also Smith 1993, 82-3; Haldon 2000a, 210; Agius 2008, 351.

added.[645] Although terminology varies, pitch is usually defined as resinous material extracted or tapped from live trees, while tar is resin extracted through the dry distillation of dead wood that has been heated for an extended period.[646]

The resinous portion of the caulking material, as well as the waterproof coating the interior and exterior of the ship's hull, is typically light brown or tan colored, the result of weathering or chemical reaction with seawater that has decomposed the original material. A gas chromatography-mass spectrometry (GCMS) analysis was conducted on six samples of the brownish-yellow coating from the interior of the ship.[647] A larger pitch clump (YK 14/16), found under PS 10B at FL 43, was also analyzed (**Figure 6.2**). The pitch mass measures approximately 19.6 cm in length, 14.3 cm wide, and 6.5 cm thick, and weighed 1.080 kg. It was bisected with a handsaw, and a piece of wood was found in the center, which may have been used to stir or handle the pitch mass when heated; the clump itself consists largely of hair.[648] Similar finds of large pitch or resin clumps, often containing inclusions of hair and rope, have been found in the excavations of Yenikapı shipwrecks. These irregular lumps were likely the form in which pitch for repairs was carried on board Byzantine ships; the lump could be heated to melt the material for applying to ship timbers as needed, possibly after mixing with other

[645] Agius 2008, 113, 150-51; see also Flecker and Foerster-Laures 1986; Humphrey et al. 1998, 345-46, 381, 451; Van der Horst 2001, 273-74; Connan and Nissenbaum 2003, 709-10; Loewen 2005: 245-46.
[646] Loewen 2005, 239. Connan and Nissenbaum (2003, 709) state that waterproofing materials on ship hulls which had undergone previous heating and was perhaps mixed with other materials should be called pitch or wood tar, while unaltered material tapped from resinous trees should be called resin. For the sake of simplicity, in this study the material has been referred to as 'pitch.'
[647] GCMS analysis of the samples was conducted by Edith Stout and Sarjit Kaur of the Amber Research Laboratory at Vassar College.
[648] Two smaller clumps between 6 and 10.5 cm in diameter were found near the shipwreck as well. The type of hair has not yet been identified.

materials. Similar cakes made from pitch products were manufactured in Europe in the early modern period.[649]

Figure 6.2: Large clump of pitch (YK 14/16) found under the hull of YK 14 during excavation.

Waterproofing mixtures made primarily or exclusively from pine or conifer were common in the Mediterranean since antiquity.[650] Theophrastus and Pliny the Elder describe the collection and manufacturing techniques for pitch and tar used in the ancient Mediterranean, which are virtually identical to techniques used in later periods.[651] Typically a resinous tree was either scored to collect resin in a container or pit over an extended period, or the entire tree was felled and heated in an oxygen-reducing

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[649] Loewen 2005, 239.
[650] Meiggs 1998: 467-71. Large amounts of solid and liquid pitch, 'pine distillate' and 'cedar oil' are listed in the naval inventories in the *Book of Ceremonies* and mentioned in Leo's *Taktika* (Pryor and Jeffreys 2006: 562, 570, 575, 646).
[651] Pliny, *HN*. XVI. 38. 52-60; see also Muller 2004, 345; Loewen 2005, 240-45.

environment (typically a pile of logs almost entirely covered with sod) in order to extract oils and tars, which flowed out of the bottom of the pile as it was burned over several days.[652] Several grades of pitch and oils could be obtained in this way.[653] Analysis of samples from the interior of the YK 14 pitch clump and a similar clump from YK 11 indicate that they were made from pine pitch heated in the range of 300-350º C, rather than tapped pine resin; the presence of methyl benzoate in the samples is ascribed to the use of Aleppo pine (*Pinus halepensis*).[654] This is consistent with Pliny's description of the production of tar for "protecting ship's tackle and many other applications."[655] Due to the chemical decomposition of the materials, similar detailed information could not be obtained from the other samples taken from YK 14.[656]

3) Rope

Based on textual and published archaeological evidence, a wide variety of materials were used for rope and cordage aboard ships in antiquity; the types of materials used often reflect what was locally available as well as other factors. Fibers from the hemp (*Cannabis sativa*) and flax (*Linum usitatissimum*) plants were probably the most commonly used materials in the ancient Mediterranean for cordage as well as textiles.

[652] Theophr. *Hist. Pl*. IX. I.7- III. 3-4.
[653] Pliny, *HN* XVI.38.52-60.
[654] E. Stout, personal communication. If the pitch was made from Aleppo Pine (*Pinus halepensis*), it was likely imported to the Sea of Marmara area since this species is not native to Anatolia and is difficult to distinguish from *Pinus brutia*; the nearest region where *Pinus halepensis* is abundant is the North Aegean and Greece (Davis 1978.5:75; see also Meiggs 1998, 43-4).
[655] Pliny, *HN* XVI.38.52-3; see also Theophr., *Hist. Pl*. IX.3.1.
[656] This information is from an unpublished report by Sarjit Kaur, Edith Stout, and Vanora Estridge of the Amber Research Laboratory at Vassar College (ARL report #185). A sample of white material scraped from the surface of a coak was described as badly degraded but similar in composition to the other pitch samples.

Most Byzantine villages in Thessaly, Macedonia, Thrace, and Anatolia grew hemp and flax.[657] The use of hemp for rope in maritime contexts is mentioned in a number of Byzantine texts.[658] Flax can also be used for making rope, and was widely used since the Bronze Age to manufacture linen cloth; linen production was a major industry in medieval Constantinople, and linen was the major material used to make sail cloth.[659] Classical Greek and Roman authors mention at least seven different materials used for ropes in the ancient Mediterranean, including hemp, flax, date palm (*Phoenix dactylifera*), rushes (Juncaceae family), genista (*Spartum junceum*), linden or lime tree bast (*Tilia* sp.) and esparto grass (*Marochloa tenacissima* or *Stipa tenacissima*).[660] Rope from the ninth-century Tantura B shipwreck found off the coast of Israel was made of rushes (Juncaceae), while rope found on the late-ninth-century-Bozburun shipwreck was made of palm fibers (Arecaceae) from the Chamaedoroid subfamily.[661] Early medieval anchors found on the shores of the Dead Sea were found with fragments of rope attached to them made from date palm (*Phoenix dactylifera*), whose leaves and fruit stalks are sources of fibers for cordage.[662] In one of the Cairo Geniza letters dated between 1060 and 1090, 'Rūm' (Byzantine) merchants are recorded as purchasing date palm fibers in Cairo for baskets and rope; similar purchases by Byzantine traders could account for the

[657] Laiou and Morrisson 2007, 66.
[658] Dennis 2010, 504-5; see also Ashburner 1976, 92.
[659] Whitewright 2007, 289.
[660] Charlton 1996, 144-46.
[661] Gorham 2000, 140; Gorham and Bryant 2001, 291.
[662] Oron et al. 2008, 299-300; see also Barreveld 1993, 182-89. Barreveld (1993, 185-88) notes that the long, flexible fruit stalks of the date palm are particularly favored for applications requiring strong cordage today, such as climbers' ropes and saddle girths.

palm-fiber rope fragments found on the Bozburun ship.[663] A variety of reeds, rushes, and grasses were also exploited for rope in Egypt since the pharaonic period.[664]

Bast cordage is made from stripping the inner bark or cambium layer from the trunk of a tree or stalk of a plant. The bast fibers are soaked and physically worked to separate the fiber bundles and make the material more flexible and easily plaited into rope.[665] Fiber samples from two rope fragments found in the YK 14 excavation area appear to be tree bast, possibly from a linden/lime species. Bast rope made from small-leafed lime (*Tilia chordata*) has a significantly different structure from other commonly used materials for rope such as hemp and flax (**Figures 6.3-6**), although all three species would likely have been available in the region around Constantinople.

[663] Jacoby 2000b, 45, n. 85; see also Goitein 1967, 44, 401, n. 17; Gorham 2000, 141.
[664] Rope coils found with other ship's supplies at the Middle Kingdom cave and harbor site of Mersa Gawasis on the Red Sea coast of Egypt were made from species of reeds (probably *Phragmites australis* or *Arundo donax*) (Veldmeijer and Zazzaro 2008, 26). Two grass species, both known as halfa grass, were commonly used for rope in ancient Egypt and are still exploited for matting, basketry, and cordage in rural Egypt; other grass species such as papyrus were also exploited for rope in ancient Egypt (Lucas and Harris 1999: 134-35).
[665] Charlton 1996, 9-10; see also Wild 1970, 16, 27-30. Animal products such as leather and animal and human hair were often used for rigging and fishing nets; see Black and Samuel 1991, 220; Bass et al. 2004, 414; Magnus 2006, 28-9; Sandars 2010, 18. Magnus (2006: 28) states that only rawhide, withy, bast or plant fibers are suitable for rigging.

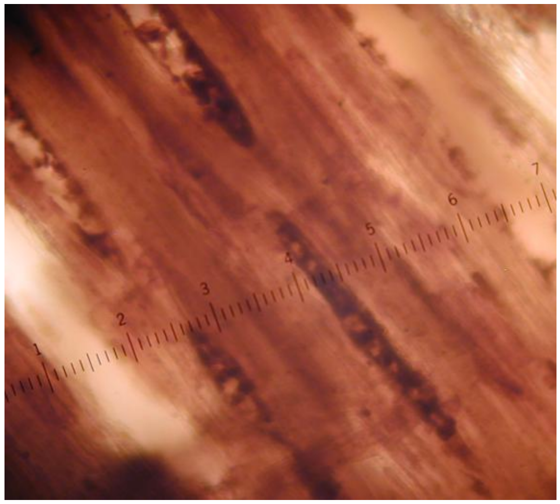

Figure 6.3: A sample of bast rope, possibly linden bast, from the YK 14 shipwreck site (Rope Fragment #1, x100 magnification).

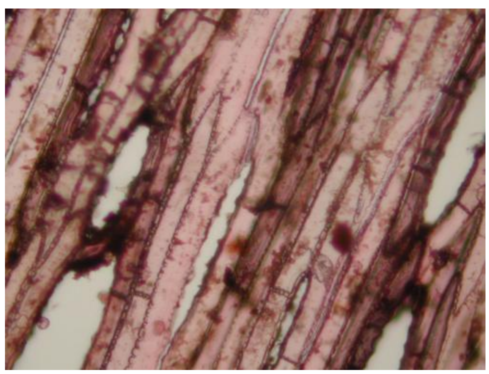
Figure 6.4: Modern sample of linden bast (*Tilia chordate*) (x100 magnification) (Sample provided by Cemal Pulak).

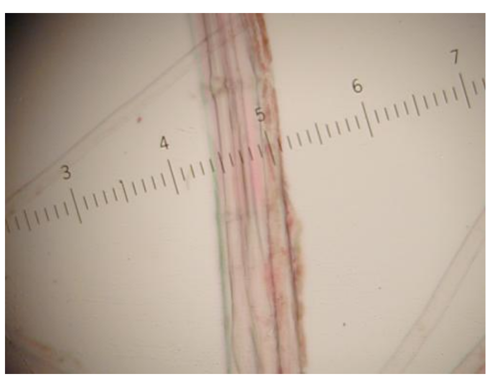

Figure 6.5: Flax fiber from modern flax rope (x100 magnification) (Sample provided by Neil Gladwell of the Traditional Rope Company in Poole, Dorset).

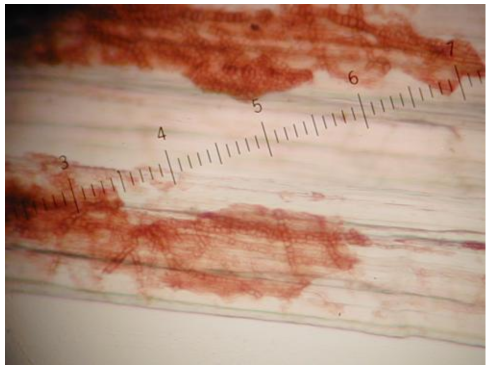

Figure 6.6: Hemp from modern rope (x 100 magnification) (Courtesy of Neil Gladwell of the Traditional Rope Company in Poole, Dorset).

Lime tree or linden tree bast (*Tilia* sp.), particularly from small-leafed lime (*Tilia chordata*) was frequently used for hand-plaited rope on northern European ships until the later Middle Ages; young linden trees supplying lengths of bast could be replaced by new trees at a harvestable size in 9-12 years.[666] Theophrastus mentions the use of lime bark for ropes and baskets as well.[667] Linden-bast rope is more durable in wet conditions than hemp, but in later periods it was generally replaced by hemp due to the greater ease by which large volumes of hemp rope could be produced using more sophisticated equipment.[668] Evidence for the use of linden or lime-tree bast in the Byzantine Empire is more limited but it was considered economically useful; Dunn notes that linden or lime bark is mentioned as an economically useful product in Byzantine documents.[669] The naval inventories in the *Book of Ceremonies* include an entry for anchor cables of linden bast for Byzantine war galleys, probably due to the material's durability in water; other lines are specified as *spartinai*, possibly genista or esparto grass, another species used

[666] Sandars 2010, 18-9; see also Magnus 2006, 31-2.
[667] Theophr. *Hist. Pl*. IV 15, 1; V. VII. 5.
[668] Magnus 2006, 27-29; see also Horsley 1978, 192-218; Sanders 2010, 18-9.
[669] Dunn 1992, 280.

for producing rope that is durable in water.[670] Four species from the genus *Tilia* are found in Europe, generally in cooler, wetter areas of the Mediterranean and Black Sea: *Tilia rubra, T. cordata, T. platyphyllos, T. argentea,* and the hybrid *Tilia vulgaris/europea*.[671] Davis notes the modern distribution of the species of *Tilia* in the region of Turkey and the Black Sea: *T. rubra* in the Crimea and Balkans, *T. argentea* in the region of Istanbul, Thrace and the Sea of Marmara, *T. cordata* in most of temperate Europe (the species used for rope in the Baltic region), and *T. platyphyllos* on the Sea of Marmara and Turkey's Black Sea coast.[672] If the rope material is in fact linden bast, it seems likely that it is from a species available in the Sea of Marmara region.

Although this evidence cannot be considered conclusive, it seems likely that the timbers, pitch, and rope materials from YK 14 all originate in the area of Constantinople or the Sea of Marmara. The association of the pitch and caulking material with the origin of the

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[670] Pryor and Jeffreys 2006: 213, 563. The use of the term *spartinai* is problematic: it may refer to esparto grass (*Marochloa tenacissima* or *Stipa tenacissima*) or a species of halfa grass (*Demostycha bipinnata* or *Imperata cylindrica*) (Wendrich 1999: 147-48; Haldon 2000: 227, 229, 233, 283; Pryor and Jeffreys 2006: 213, 563). According to Pliny the Elder, esparto grass as well as date palm was preferred over hemp for anchor cables due to their greater durability in water (Pliny *HN* XVI.37.89; XIX.8.29-30). Esparto grass ropes are known from a number of shipwreck sites in the Mediterranean as well as from textual sources of the Roman period (see Charlton 1996, Appendix 2). However, esparto grass is found primarily in North Africa and the western Mediterranean only as far as southern Italy and Sicily. Since the invasion fleet was from Anatolia, Cemal Pulak (personal communication) suggests that *spartium* was used as a generic term in this case to denote ropes made from a similar type of grass; similar species grow in coastal areas of Anatolia and the Aegean. One possibility is genista or broom (*Spartum junceum*), which was known as *spartoi* in Greece during the first century C.E., according to Pliny the Elder (see also Charlton 1996, 26). Turrill (1929, 146-47) notes the presence of this species in Thessaly and Epirus in northern Greece. Pliny also implies in at least two passages that in earlier times different rope materials were used in nautical contexts rather than esparto grass, which suggests that it was transplanted eastwards during or before the Roman imperial period (Charlton 1996: 25-6; see also Casson 1995, 10, n. 27).

[671] Polunin 1976: 139-42; see also Davis 1967.2: 422-24.

[672] Davis 1967.2: 422-24. *Tilia chordata*, the species used for rope on many medieval ships from the Baltic, has been reported in the Istanbul area and is widespread in Europe, although Davis states that its presence in Turkey "needs confirmation" (Davis 1967.2: 421-23).

ship would necessarily be less certain than that of the timber: It is possible that some materials, such as the pitch, were imported from further abroad (although Constantinople would be a likely destination for such material), or, pitch and caulking for repairs could be obtained locally at an area other than the ship's home port. But a local origin for the materials used in YK 14 is consistent with the relatively economical construction features of the ship and the significant evidence in the hull for repairs and years of use; the owner or owners of the ship seem to have favored a small, inexpensive coaster, and, so far, there is no sign that the ship was used for long-distance voyages.

CHAPTER VII

YENİKAPI 14 AND OTHER LATE ROMAN AND BYZANTINE-ERA SHIPWRECKS

The significance of many of the construction features of the YK 14 shipwreck can be understood only through comparison with other archaeologically documented shipwrecks. The most relevant examples date from the later Roman Empire to the early eleventh century, but shipwrecks outside of this period also provide important evidence for the development of the technological tradition that produced YK 14 and the other Yenikapı ships. YK 14's hull remains show links to older shipbuilding traditions as well as evidence for newer innovations and adaptations to the economic conditions of the tenth-century Byzantine Empire.

Study of the development from shell- to skeleton-first shipbuilding has occupied much of the last fifty years of research on Mediterranean maritime technology from the Bronze Age to the early Middle Ages. Shell-first ship construction methods in the ancient Mediterranean up to the late Roman Empire and early Byzantine period are characterized by the use of permanent edge-fastened hull planking. One major aspect of this process is the gradually decreasing role and eventual abandonment of this method. In the Mediterranean, as elsewhere, the construction methods used throughout history for some types of vessels do not fit neatly into either the categories of 'shell-first' or 'skeleton-first' construction, resulting in definitions of 'mixed construction', 'framing-first', and 'bottom-based' building for vessel types with a combination of features.[673] Many of the excavated vessels of the Late Roman and Byzantine periods fall into these more ambiguous categories. In order to understand the significance of the technology and design features seen in the construction of YK 14, the available evidence for Mediterranean ship construction methods must be examined.

1) Early Methods of Mediterranean Hull Construction: Archaic Laced Hulls and Pegged Mortise-and-Tenon Hull Construction

The earliest true plank-built wooden vessels in the Mediterranean were built shell-first. Ancient Egyptian vessels of the mid-third millennium B.C.E. were constructed with planking edge-fastened by a combination of lashings, caulked seams, and wooden tenons.[674] On the Syro-Canaanite coast during the Late Bronze Age, shell-first ship construction developed into a variant using large, closely-spaced, pegged-mortise-and-tenon joints, which edge-fastened thick cedar planking; with minor modifications, this style of edge fastening continued into the Roman period.[675]

Another method of shell-first construction involving the lacing together of planks through holes drilled along their edges is first seen in Mediterranean shipwrecks dating from the sixth through fourth centuries B.C.E. Wooden dowels driven into drilled holes

[673] Basch 1972, 17-9; see also Greenhill and Morrisson 1995, 51-61; Pomey 2004, 28-9; Hocker 2004b.
[674] Steffy 1994, 23-37; see also Ward 2000, 138-43.
[675] Bass 1967, 50; see also Pulak 1999; 2003; Pomey et al. 2012, 291-92.

or in the edges of hull planks supplemented the lacing in some ships, while unpegged mortise and tenon joints were used in others; plank seams were plugged with luting or caulking held in place by the lacings and sometimes with battens. Frames were widely spaced in these hulls and lashed to cleats in the planking.[676] By the late sixth century B.C.E., a shell-first construction style appears using both laced construction for some aspects of the hull, such as the keel/garboard connections, while the main body of the ship was built with mortise-and-tenon joints. This style of construction was used on the late sixth-century Jules Verne VII and César I ships excavated in Marseille, as well as on the Ma'agan Mikhael shipwreck, a Greek vessel that sank off the coast of Israel around 400 B.C.E.[677] Although the use of laced plank seams in vessel construction fell out of use in most parts of the Mediterranean by the fourth century B.C.E., it survived in the Adriatic through the Roman period and into the early Middle Ages, and was a standard feature in vessels of the Red Sea and Persian Gulf into modern times.[678] These methods provide early precedents for several of the techniques and features seen in the Byzantine period at Yenikapı, including the use of dowels or coaks as planking edge fasteners and the use of caulking in plank seams.

[676] These methods of construction, with minor variations, are seen in the sixth-century B.C.E. shipwrecks from Giglio on the Italian coast, Jules Verne 9 and Bon Porte excavated in France, the Cala Sant Vicenç wreck from the Balearic Islands, and the Pabuç Burnu shipwreck excavated on the southwestern coast of Turkey near Bodrum (Pomey et al. 2012, 291-93; see also Rieu et al.1980; Pomey 1981; 2001; Bound 1991; Coates 2001, 154-57; 2001; Kahanov 2003, 54-5, 113-22; Greene et al. 2008, 700-3; Nieto and Santos 2010, 48-9; Polzer 2010, 31-6).
[677] Kahanov et al. 2003, 55-6, 65; Pomey et al. 2012, 292-93.
[678] Berti 1990, 29-42; see also Hourani 1995, 89-97; Kahanov 2003, 66-76.

By around 300 B.C.E., when the Kyrenia ship sank off the north coast of Cyprus, shell-first construction involving planks fastened with regularly-spaced pegged mortise-and-tenon joints had become the norm in the Mediterranean shipbuilding. This technique, along with other shell-first hull construction characteristics, occurs with very little variation in Mediterranean ships for almost one thousand years. As one of the best preserved and documented hulls built with mortise-and-tenon joints, and one of the earliest excavated, the Kyrenia ship serves as an example of the basic characteristics of a Greco-Roman ship shipbuilding tradition from the Classical to early Byzantine periods.

The Kyrenia ship was approximately 14 m long, 4.2 m in beam, and had a cargo capacity of approximately 25 tons burden.[679] The ship was built with a rabbeted keel into which the garboard planks were inserted and edge-fastened with pegged mortise-and-tenon joints. The mortise-and-tenon joints themselves were cut into the hull's 4 cm-thick planking; they were typically 4.3 cm wide on average, 8-10 cm deep, and driven about 12 cm apart on average.[680] While difficult to assemble, the resulting hull was extremely rigid due to this construction method: the mortise-and-tenon joints essentially serve as small internal frames, and frames were generally not needed to support the hull until after the entire shell had been constructed. The frames themselves were relatively small in diameter (approximately 9 x 9 cm in cross section), and were arranged as alternating floors, that spanned the bottom of the hull to the turn of the bilge, and pairs of half-

[679] Steffy 1985a, 100; 1994, 54-5.
[680] Steffy 1994, 43, 48.

frames, that ran from the keel to the caprail on either side of the ship.[681] The frames were fastened to the hull with double-clenched copper nails driven through treenails.[682] The ship's frames exhibit a number of features typical of frames in shell-built vessels: the frame components were not attached to each other or to the keel, and had rounded frame faces and numerous irregularities, since it was unnecessary to shape them into the more standardized forms of pre-fabricated 'control' frames used in skeleton-first construction.[683]

The ship was probably several decades old when it sank; the hull showed clear evidence for many repairs and maintenance episodes.[684] Instead of caulked plank seams, the outside of the hull was pitched. This was sufficient for keeping the hull water-tight, particularly because the hull timbers—including the mortise-and-tenon joints—swelled once they were immersed, forming a tight seam. At some stage long after the ship's construction, the hull was sheathed in lead, as well as an additional layer of pine planking in the bow.[685] Lead sheathing was commonly used in the late Hellenistic and early Roman period until about the second century C.E. for protecting ships' hulls from marine organisms; the technique was later abandoned, probably due to the expense.[686]

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[681] Steffy 1985a, 84-6.
[682] Steffy 1985a, 84.
[683] Steffy 1985a, 101.
[684] Steffy 1985a, 95-9.
[685] Steffy 1985a, 96-9.
[686] Parker 1992, 27.

Steffy notes a number of characteristics of shell-first construction in the Kyrenia ship's hull in addition to mortise-and-tenon joints. Although an attempt at symmetry is clear in the hull, it is actually asymmetrical. The dimensions and shapes of the planks were fashioned as the hull was built, and some strakes were cut in unusual shapes to adjust for deviations between the sheer on the port and starboard sides.[687] This advantage of shell-first shipbuilding was commented on in later centuries as well: a mistake in the process of construction or shaping of the hull can be spotted and easily corrected, while in skeleton building this is not always possible, since the shape of the hull is largely predetermined once the framing is erected, and the framing blocks the builder's view of the hull.[688] Longitudinal stiffening was provided by the keel and garboard strakes, by the wale timbers at and above the waterline, by the 'wine-glass' shape of the hull's cross section (the keel and garboard strakes act as a girder, giving the hull additional longitudinal strength), and by the mortise-and-tenon joints in the hull itself (**Figure 7.1**). Unlike a skeleton-built ship, no keelson was present or necessary, and repairs and modifications later in the ship's life show that the frames and keel played only a secondary role in the strength of the hull.[689] Even repair planks were added to the hull with their own tenons to replace original tenons cut during the replacement process, attesting to the importance placed on them for the hull's integrity by the shipwright.[690]

[687] Steffy 1985a, 92-3.
[688] Hasslöf 1972, 59-60.
[689] Steffy 1985a, 90, 94-7.
[690] Steffy 1995, 420-21.

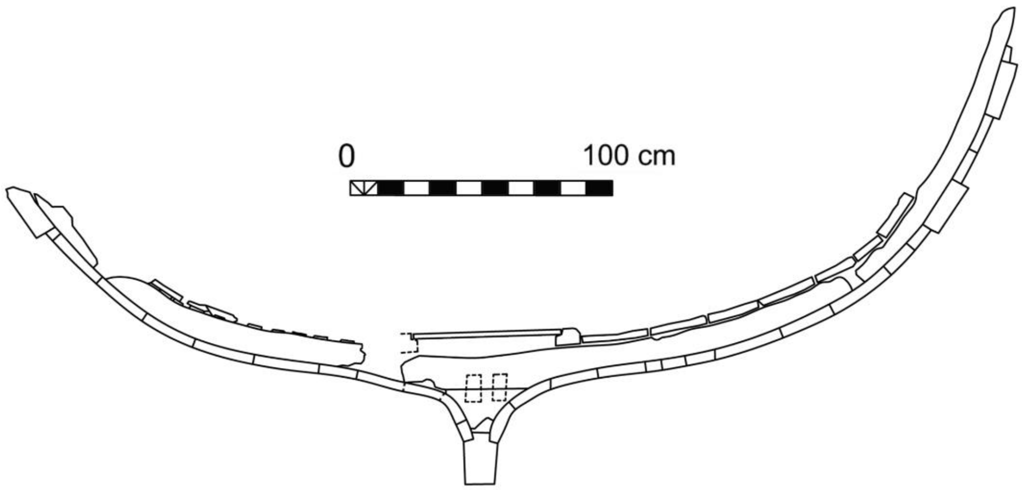

Figure 7.1: Midship cross section of the Kyrenia ship (After Steffy 1985a, 81, Ill. 6).

The Kyrenia ship's construction features are worth recalling at length for several reasons. In the Roman Republican and early Imperial period, even the large cargo vessels of this period were built using the same basic methods used in the Kyrenia ship, with only minor modifications. The ships' basic rigging and equipment (loose-footed square sails, quarter rudders, etc.), selected wood types for construction (oak or pine frames and tenons and pine planking), and other features are quite similar to ships used into the early Byzantine period. Because shipwrecks of a similar size to the Kyrenia ship are by far the most common in the archaeological record in the Mediterranean from the Classical to the early medieval period, it gives us some idea of the structural requirements of a vessel designed for the Mediterranean environment, as well as the basic features of the main construction tradition for seagoing ships in the Roman Empire.

2) Mediterranean Ships of the Roman and Early Byzantine Periods, c. 100 B.C.E.-625 C.E.

Ship construction in the Mediterranean appears to have changed little between 300 B.C.E. and the fourth century C.E. Some variation occurred due to regional construction styles, particularly in local coasters or river craft from Gaul and the Adriatic.[691] Some technological changes occurred: iron nails were occasionally used as alternatives to copper nails since the sixth century B.C.E., but eventually become common in the late Imperial period and fully replaced more expensive copper nails by the fifth century C.E.[692] Larger ships, such as the 450-ton Madrague de Giens shipwreck, which sank off the southern coast of France in the early first century B.C.E., had specific structural requirements due to their size: such ships were used to supply the imperial capitals of Rome and later Constantinople.[693] The Madrague de Giens ship was constructed with two layers of pegged-mortise-and-tenon planking, which further strengthened the hull as well as offering some protection to the inner layer of planking from marine borers.[694] Larger ships with deeper holds also required better methods of removing bilge water;

[691] Pomey et al. (2012, 299-300, 302) has also proposed a 'Western Imperial' shipbuilding tradition in the Roman period characterized by flat floor timbers (described as a 'sea-river characteristic'), rounded bilges, and the bolting of selected frames to the keel. Some variants of typical Roman vessel construction have been found in the western Mediterranean, such as the Saintes-Marie-de-la-Mer 24 shipwreck, an Early Imperial 'sea-river' craft which had several frames lashed to cleats in the planking (Long et al. 2009).
[692] Parker 1992, 27.
[693] Pomey and Tchernia 1978, 234; see also Tchernia et al. 1978, 101-7; Casson 1995, 186-89.
[694] Tchernia et al. 1978, 75-107.

many ships dating from c. 300 B.C.E. to the seventh century C.E. were equipped with chain pumps.[695]

Shipbuilding in northern Europe was changing as well. In the ‘Romano-Celtic’ construction tradition in the new Roman provinces of northwestern Europe, traditional techniques of the indigenous populations were combined with Mediterranean construction methods, often to build larger vessels than those of the pre-Roman period. The larger size of many of these vessels has been explained as a result of the increased economic demands brought by integration into the Roman Empire.[696] Characteristics of this construction tradition include the use of sawn oak for hull construction, ‘bottom-based’ vessel construction methods using temporary cleats for holding planking together during construction or actual pre-erected floors, caulking or luting in plank seams, large clenched iron nails driven through wooden treenails as hull fasteners, and, in some cases, the use of Mediterranean-style carvel planking with mortise-and-tenon joints.[697] These construction methods were largely confined to northern Europe and inland watercraft, but could have influenced Mediterranean shipbuilding, particularly in Gaul, where many flat-bottomed Roman-era river craft like those excavated in recent years in France exhibit characteristics of this tradition.[698]

[695] Carre and Jézégou 1984.
[696] Hocker 2004b, 70.
[697] McGrail 2008, 625-27; see also McGrail and Nayling 2004, 197-211.
[698] Guyon and Rieth 2009; see also Pomey 2009, 272-75; Long et al. 2009a, 285-86; Long et al. 2009b.

Between the fourth and seventh centuries C.E., significant changes begin to appear in Mediterranean ship hulls. Pegged-mortise-and-tenon joints are spaced more widely and unevenly than in earlier ships: they were roughly 30 cm apart on average in the late fourth-century Yassıada ship and the fifth century Dor D vessel, and between 30 and 90 cm apart in the seventh-century Yassıada ship.[699] The iron nails used in ship construction become smaller than the copper nails used in earlier periods; rather than being clenched over the inner faces of frame timbers, shorter nails were used that did not fully penetrate ships' frames.[700] Frame timbers were also more frequently fastened to the keels of ships, and timbers for longitudinal stiffening of the hull become more important for hull strength as well.[701] 'Active' frames used to help determine the shape of particular hull sections probably began to be used in ship construction during this period.[702] By the seventh century, the mortise-and-tenon joints in the hull are no longer major structural elements, and are used only for the lining up of one strake with the next.[703]

The rougher workmanship appearing in many Late Roman ship hulls in comparison to earlier vessels coincides with the division of the Roman Empire in the third century C.E. and the decline and eventual dissolution of its western half in the fifth century.[704] Although the political and social effects of these developments were catastrophic in some parts of the empire, commerce continued, and large parts of the eastern half of the

[699] Bass and van Doorninck 1982, 311; see also Joncheray 1975, 121-26; 1977, 5-7; van Doorninck 1976, 123; Kahanov and Royal 2001, 262; Pomey et al. 2012, 291.
[700] Steffy 1994, 80; see also van Doorninck 1976, 126, 130.
[701] van Doorninck 1976, 130-31; see also Pomey 2004, 31-4; Pomey et al. 2012, 298-301.
[702] Pomey et al. 2012, 245; see also van Doorninck 1976, 126-27.
[703] Bass and van Doorninck 1982, 55-6.
[704] van Doorninck 1976, 130; 2002a, 900; see also Joncheray 1977, 5-6; Steffy 1982a, 84; Kahanov et al. 2004, 126.

empire thrived until the early seventh century.[705] The territorial losses and political unrest of the first half of the seventh century played a role in this process, although significant technological changes occurred long before this period (see Chapter I). These losses resulted in the collapse of the government-sponsored *annona* system, which had major effects on maritime activity and, in consequence, on ship construction, particularly in the apparent disappearance of the largest ships. While understanding the specifics of these changes in ship construction presents difficulties due to the relatively few fully excavated shipwrecks from this period, it is clear that long-distance maritime trade connections in the Mediterranean were vastly reduced and had also changed in character.[706] The local or regional character of ship construction seems to have become more pronounced, a result of the political and social changes of the period. Smaller, cheaper merchant ships seem to have been a better investment in a period where resources were limited and piracy and naval warfare had again become a threat.[707] The shipwreck assemblages discovered in excavations at Yenikapı in Istanbul and Tantura Lagoon on the Israeli coast provide important evidence for these changes, complementing earlier excavations of Byzantine-era shipwrecks from the coast of Turkey and elsewhere in the Mediterranean.

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[705] Foss 1994, 45-50; see also Haldon 1995, 10-6, 111.

[706] For numbers of known shipwrecks from this period, see Parker 1992 and McCormick 2012, 81-8. The increase in the use of barrels, which rarely survive in the archaeological record on land or on shipwrecks, has been proposed as one reason for the lower rate of discovery of amphora-carrying (and therefore more archaeologically visible) shipwrecks in this period; the extent to which barrels were in use and replaced amphoras in the late antique Mediterranean is unknown, but may have been more significant than previously thought (McCormick 2012, 74-6, 91-2). The use of skins for liquids, which is common in the medieval Cairo Geniza texts, may have also decreased amphora use (Goitein 1967, 334; see also van Doorninck 2012, 131).

[707] van Doorninck 1972, 139; see also Kreutz 1976, 80, 105-9; Whitewright 2011a, 102; 2011b; 2012.

3) The Yenikapı Shipwrecks

The majority of 36 shipwrecks discovered during the Yenikapı excavation include a wide variety of cargo vessels, several of which are the closest archaeological parallels to YK 14 and seem to be the products of the same regional shipbuilding industry. Detailed information on many of the shipwrecks is not yet available because their excavation has only recently been completed. However, useful comparisons can be made between YK 14 and several other vessels from the site, particularly shipwrecks documented by INA which have been under study since their recovery between 2005 and 2008. Preliminary reports on a number of the 28 Yenikapı shipwrecks documented by Istanbul University have also been published.[708]

Shipwrecks from the Yenikapı site consist of several categories of vessels. Six shipwrecks are rowed longships dating to the ninth or tenth centuries, probably small warships of the Byzantine navy.[709] Thirty of the shipwrecks are roundships of various types, including merchant or cargo vessels of various sizes and possibly some other specialized types such as fishing vessels, ferries, etc. The shipwrecks from Yenikapı span the period from the fifth to early eleventh centuries C.E., with a majority dating

[708] Published preliminary reports on the eight Yenikapı shipwrecks excavated by INA include Pulak 2007a; 2007b; 2007c; 2007d; Liphschitz and Pulak 2007/2008; 2009; Pulak et al. 2013; Ingram and Jones 2010; 2011. Preliminary reports from Istanbul University's documentation of the shipwrecks include information on the roundships YK 3, 6, 7, 8, 9, 12, 15, 17, 20, 22, 27, 29, and 31, as well as more limited information on galleys YK 13, 16, 25, and 36 (Başaran et al. 2007; Başaran and Kocabaş 2008; Kocabaş 2008; 2010; 2012a; 2012b; Türkmenoğlu 2012; Kocabaş and Özsait-Kocabaş 2007; 2010; and Özsait-Kocabaş 2012. Pomey et al. (2012, 279-85, 290) also includes some information on the Yenikapı shipwrecks.

[709] Pulak 2007a, 203; see also Dennis 2010, 507, 517; Kocabaş 2012a, 108.

from the ninth and tenth centuries.[710] Some of these ships appear to have been abandoned as derelicts, while others appear to have sunk in storms and were quickly buried, including YK 14, sunk in a storm in the ninth- or early-tenth century, and YK 1, 2, 4, 5, and 24, which may have sunk in a later storm in the late tenth century.[711] Six of the eight shipwrecks documented by the INA project at Yenikapı are roundships of different types, ranging in date from the seventh to late tenth or early eleventh century C.E. (see Table 1.1 in Chapter I). All were single-masted vessels rigged with a lateen sail, and would have been steered with a pair of quarter rudders (see Chapter V).[712]

YK 11[713]

YK 11, excavated in the summer and fall of 2008, is a small merchantman discovered in 2006 towards the western end of the Marmaray excavation site (**Figure 7.2**). This area was one of the first sections of the harbor to suffer the effects of silting from the Lykos River; the Late Roman and Byzantine-period deposits here consist of dark, anaerobic mud with shell inclusions mixed with refuse and artifacts dumped in the harbor. Organic remains in these deposits were very well preserved. Pottery and other artifacts in the stratigraphic layer of YK 11 and inside the vessel indicate an early seventh-century date for the ship.[714]

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[710] Pulak 2007a, 203-5; see also Liphschitz and Pulak 2009, 164; Kocabaş 2012a, 107.
[711] Pulak 2007a, 203. Twenty-five shipwrecks are in this stratigraphic layer; many of these ships probably sank in two storms in the tenth and early eleventh centuries (Perinçek 2010, 206, 209-11, 215).
[712] Pulak 2007a, 211.
[713] Information on YK 11 was provided by Rebecca Ingram, who has been studying the hull remains.
[714] Ingram and Jones 2010, 13.


Figure 7.2: The YK 11 shipwreck, after its initial excavation in the spring of 2008.

The bottom of the ship and one side of the hull was preserved to just above the waterline. The shipwreck covered an area of approximately 9.5 x 4 meters, while the ship itself has been reconstructed as about 12 meters in length and 4 meters in beam.[715] Teredo worm holes in the upper section of the hull indicate that the ship was exposed for a significant period of time after sinking, probably after its abandonment as a derelict.[716] Despite this, the hull timbers were well preserved. Surviving hull elements include planking, two wales, frames, and a three-part keel of Turkey oak (*Quercus cerris*) connected with keyed hook scarfs; internal timbers include stringers, ceiling planking, and part of a bulkhead partition at the ship's stern. Almost all of the ship's planking and

[715] R. Ingram, personal communication.
[716] Ingram and Jones 2010, 13.

a majority of frames and other internal timbers were made of Turkish pine (*Pinus brutia*), but some frames of Turkey oak and timbers of European elm (*Ulmus campestris*), Tamarisk (*Tamarix* X 5), and Mediterranean cypress (*Cupressus sempervirens*) were also found. The cross section of the ship exhibits a shallow 'wine-glass' shape common on earlier Greek and Roman seagoing ships.

YK 11 was built using hull planks 2-3 cm thick. Original hull planks were edge-fastened with unpegged mortise-and-tenon joints. These joints showed significant variation in spacing throughout the hull where they survived, but were spaced about 45 cm apart on average. Well-preserved caulking was found in the plank seams of the ship. The framing consisted of floors alternating with paired half-frames; the cross sectional dimensions of the floors range from 7.4 to 12.3 cm molded and 7.4 to 9.9 cm sided, while those of the half-frames range from 6.9 to 9.7 cm molded and 7.4 to 9.2 cm sided. All frames crossing the keel were fastened to it with short iron nails. Nails were also used exclusively for fastening the planking to the frames, and no treenails were found in the hull. The keel and endpost scarfs were fastened with iron bolts.

Many internal timbers were preserved in the hull. Longitudinal timbers fastened to the inner faces of the frames consisted of five stringers on the port side, each 4-7 cm thick, ceiling planks between the stringers, a sternson made from a recycled keel timber, and a short stemsom, both of which were originally bolted to the keel timbers at the locations of the scarf ends.[717] A grooved, transverse internal timber was installed near the stern for a bulkhead; and three pairs of stanchion blocks with mortises cut in their inner faces were positioned in the bottom of the hull to either side of the keel. Two pairs of these mortised blocks were likely for stanchions for supporting a deck or deck-level through-beams, while the third pair are likely to be mast-step sisters used in fixtures supporting the mast or mast-partner beam.[718]

YK 11's hull is notable for evidence of extensive repairs: about half of the hull planking and a significant number of the ship's floor timbers had been replaced. Based on comparison of nail holes, the large number of unmatched holes in the original planks and frames, and the presence of certain obvious repair pieces, R. Ingram concluded that at least two major repair episodes occurred involving the installation of new frames in the hull, as well as an unknown number of repair episodes involving the replacement of hull planks. Original hull planks below the first wale were all edge-fastened with unpegged mortise-and-tenon joints, which continued to the first wale at the waterline. Above the first wale, the hull was built around pre-erected frames.

YK 11's characteristics are remarkably similar to the contemporary seventh-century vessels from Yassıada excavated off the southwestern coast of Turkey and St. Gervais

[717] After one of the repair episodes in which frames were replaced, both the stemson and sternsom timbers were removed and later nailed, rather than bolted, in place.
[718] Transverse bulkhead timbers similar the YK 11 example were also found on YK 29, tentatively dated to the eighth century, and the Tantura E shipwreck, dated between the seventh and ninth centuries (Kocabaş 2012a, 10, Fig. 15.9; see also Israeli and Kahanov 2012, 45, Fig. 6.4).

on the Mediterranean coast of France.[719] Other vessels from Yenikapı constructed with unpegged mortise-and-tenon joints include YK 22, the largest shipwreck found at the site, dating from of the fifth to early seventh-century C.E., YK 34 and 35, and the remains of an unknown number of mortise-and-tenon-built vessels in the form of disarticulated hull planking fragments found across the site.[720] These ships are clearly descended from Classical period vessels such as the Kyrenia ship. Although the exact time range that mortise-and-tenon construction fell out of use at Yenikapı will remain unclear until the excavated material is fully studied and published, it probably occurred some time in the later seventh or eighth century, some decades after the end of the *annona* system. If the use of mortise-and-tenon joinery in hull planking was still fairly common in the ninth century, mortise-and-tenon joints would likely be found in the hulls of ships of this period or in the edges of repair planks used in later ships. This has not been the case with the ships excavated by INA at Yenikapı, or on the ninth-century shipwreck from Bozburun.

YK 23

YK 23 was discovered in the spring of 2007, when it was damaged by a machine boring holes for concrete pilings to construct a retaining wall along the eastern side of Namik Kemal Street (**Figure 7.3**). Although numerous fragments of the hull were recovered from the sediment removed by the boring machine, the bore holes were subsequently filled with concrete, which left four 1.5 meter-diameter concrete pillars in the side of the

[719] Bass and van Doorninck 1982; Jézégou 1992.
[720] Kocabaş 2012a, 109; O. Köyağasıoğlu, personal communication, May 13, 2013.

ship as well as adjacent timbers broken and splintered by the action of the drill. Despite the damage, the shipwreck was fairly well preserved. The hull remains covered an area approximately 9.0 x 4.5 m, and consisted of just over half of the ship's bottom, with one side of the hull—unfortunately the side damaged by the boring machine—preserved to the waterline. The hull was found in a layer of fine gray sand with shell and artifact inclusions; the ship may have sunk in a storm, with its cargo dispersed in the harbor or salvaged soon afterwards.

Figure 7.3: Photomosaic of the YK 23 shipwreck by S. Matthews. Concrete pilings for the retaining wall are visible at the top of the photomosaic.

YK 23 is a heavily-built merchantman that most likely sank in the early or mid-ninth century based on the dates of coins found within the ship's hull and artifacts found in the ship's stratigraphic level; no cargo was found other than a few isolated artifacts. The ship was originally about 15 meters in length and 5 meters in beam, and built from Turkey oak (*Quercus cerris*). Three rabbeted keel and endpost timbers survived and were connected with keyed-hook scarfs; an iron bolt was used to secure the hook scarf between the main keel timber and a transitional curved keel piece. The cross section of the ship is of a shallow 'wine-glass' shape similar to that of YK 11. The main keel timber itself is quite massive, with molded dimensions of approximately 26-33 cm and sided dimension of 17.5 cm, much larger than that seen on any of the other vessels documented by INA at Yenikapı. A single transverse hole, similar to those in the keel timbers of YK 14, was cut through the port and starboard faces on the main keel timber near amidships.[721] The garboards and hood ends of the hull planks were fastened to the keel timbers with iron nails. The ship had 27 extant frames following the same pattern of floors alternating with paired half-frames seen on YK 11 and many earlier ships. These frames are large timbers in comparison to those of YK 14, with the floors' sided dimensions in the range of 8-14 cm, and molded dimensions in the range of 12-25 cm; the maximum molded dimensions on the frames occur in the keel area. Score marks were noted during the excavation at frame edge locations on the inner faces of many of the hull planks. Frames were attached to the hull planking only with iron nails—no treenails were used—and 14 of 18 frames crossing the keel were nailed to it. Futtocks were not attached to the floor timbers. A complete longitudinal timber, most likely a sternsom, was nailed to the tops of the frames over the keel at the better preserved end of the ship (**Figure 7.4**). Three wales, separated by strakes of hull planking, were preserved

[721] Wear around the transverse hole concentrated on the side of the hole closer to the more poorly preserved end of the ship. On YK 14, this wear was on the forward side of the 'tow holes'; this observation, as well as the fact that only one hole was preserved on YK 23, and on the vessels where both holes are preserved, they tend to be located amidships and towards the bow, suggests that the better preserved side on the YK 23 shipwreck is the stern.

on one side of the ship. An aperture in the planking, possibly for a through-beam, survived in the midship area, between the concrete pillars, above one of the wales.

Figure 7.4: Longitudinal sternsom (?) fastened to the inner faces of the frames in the better-preserved end of YK 23.

The hull planking of YK 23 was fastened with regularly-spaced coaks. The positions of some of these edge fasteners were marked by scoring on the hull planking. The coaks were used as edge fasteners only up to the first wale at the waterline, above which the hull's shape was determined by installed frames. The hull showed signs of extensive repairs, including repair planks, as well as caulking and pitch repairs to areas of teredo worm damage and rot; this evidence suggests that the ship had been in service for a number of years before sinking.

Many of the design features of YK 23's hull have clear precedents in earlier ships from Yenikapı and in Roman and Byzantine ships from other sites; these include the ship's framing pattern, the exclusive use of iron nails and bolts as hull fasteners, the basic hull shape (i.e., the 'wine-glass'-shaped cross section), and the ship's heavy scantling. However, some new features are present as well. First, YK 23 is the earliest of the six Yenikapı roundships studied by INA to have been built primarily with oak, the most common shipbuilding wood for roundships from Yenikapı after the seventh century.[722] The replacement of unpegged mortise-and-tenon joints with coaks is also significant (**Figure 7.5**). YK 23 is the earliest of the Yenikapı ships documented by INA with regularly-spaced coaks used as edge fasteners between planking, and they are used in the same manner in YK 23's hull as they are in later roundships from the site.

[722] YK 11 follows Theophrastus' recommendations for using fir or pine planking and the more durable oak for keel timbers, while YK 23 and most of the later roundships are built primarily or entirely of oak (*Hist. Pl.* V.VII.1-3.).

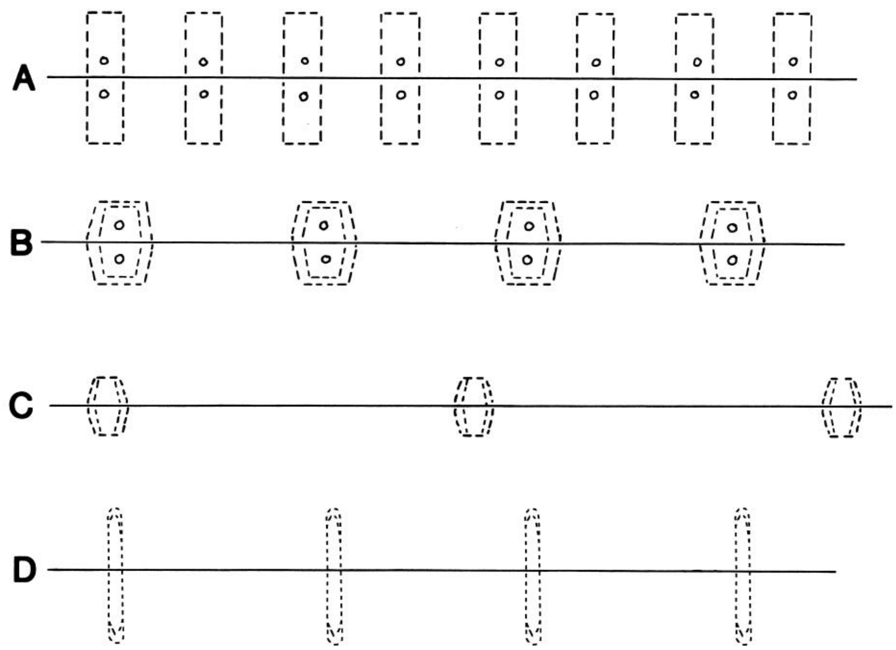

Figure 7.5: The development of edge-fastened planking in eastern Mediterranean ship construction based on shipwreck remains: a) The Kyrenia ship, c. 300 B.C.E.; b) the fourth-century C.E. Yassıada ship; c) the seventh-century C.E. Yassıada ship; d) Yenikapı Wrecks 23, eighth century C.E., YK 14, c. 900 C.E., and YK 1, 5, and 24, later tenth century C.E. (Adapted from Steffy 1994, Fig. 4-8).

YK 5

YK 5 is a well-preserved, medium-sized roundship discovered near the eastern end of the site in late 2005 and excavated in the summer and fall of 2006 (**Figure 7.6**). The ship's cargo and equipment was probably dispersed and salvaged aside from several iron objects found in the hull. YK 5 was found in a sandy layer partly covering one side of the galley YK 4, and dated by artifact finds and radiocarbon dates to the late tenth century C.E.[723] The ship's position, as well as the lack of shipworm damage in the timbers of both shipwrecks, seems to indicate that YK 5 may have collided with YK 4

[723] Liphschitz and Pulak 2009, 167.

during the same storm that buried up to 25 ships in the same stratigraphic layer in the later tenth century.[724] The almost complete absence of evidence for repairs in the ship's hull (there is a single repair to the ship's preserved endpost), the fact that little or no dry rot damage was found under frame positions, and the excellent condition of the ship's timbers indicate that the ship was relatively new when it sank.

Figure 7.6: YK 5, a cargo vessel dating to the late tenth century, during excavation in April 2006.

[724] Pulak 2007a, 203, 211; see also Perinçek 2010, 206.

About one third of YK 5's hull was preserved. Nine strakes were preserved on the starboard (SS) side, up to the beginning of the turn of the bilge, and thirteen strakes, were preserved on the port (PS) side, including one wale. The preserved remains of YK 5 were preserved in an area about 12 x 3.5 meters, and represent the remains of a hull that was originally approximately 14.5 meters long and 5 meters in beam. Thirty-three floor timbers (FL 3-FL 35), seven floor positions indicated only by frame fasteners on the planking, and five partially preserved futtocks were preserved on the shipwreck.[725] The hull of the ship was built entirely of Turkey oak (*Q. cerris*).[726]

Of the Yenikapı ships recovered by INA, YK 5 is the closest in construction and design to YK 14. YK 5 was similar in size to YK 14, but has a much wider and flatter-floored hull shape, probably to maximize cargo space. Two keel timbers were preserved, consisting of an intact main keel timber and a short, curved transitional piece, as well as a partially preserved endpost; unlike YK 11, 14, and 23, on YK 5 none of these timbers were rabbeted. The keel and endpost tapered along the length of the ship, and have smaller cross-sectional dimensions closer to the stern of the ship, as on YK 14.

YK 5 was also built with L-shaped, in-line floors, but these are straighter than those used on YK 14, giving the ship a cross section similar to the roughly contemporary Serçe Limanı ship (**Figure 7.7**).[727]

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[725] Liphschitz and Pulak 2009, 167.
[726] Liphschitz and Pulak 2009, 167.
[727] Bass et al. 2004, 157.

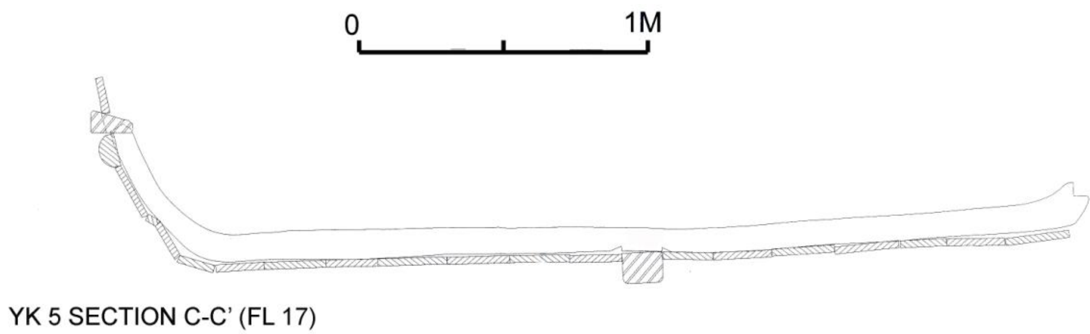

Figure 7.7. Cross section of YK 5 amidships at floor FL 17 and the mast partner. Note the hull's flat bottom and hard chine at the turn of the bilge, the lack of rabbeting on the keel, and the stump of a through-beam in the upper part of the hull at left (Section by Sheila Matthews).

These floor timbers were also somewhat more robust than those on YK 14. The largest floors were 3.0-3.4 m long. The average minimum and maximum molded dimensions of the floors are 8.6 cm and 12.7 cm, respectively, while the average minimum and maximum sided dimensions are 5.3 cm and 7.5 cm, respectively. YK 5's frames consist of L-shaped floors scarfed to in-line futtocks with the same type of scarf ends seen on YK 14. As on YK 14, in some cases the futtock scarfs of the floors were also cut through treenails at the ends of the 'short arm' ends of the floors. The lower ends of five broken futtocks were also recovered from the wreck. Frame fasteners consisted primarily of treenails of Turkey oak (*Q. cerris*) supplemented in some areas with nails, usually at the turn of the bilge and garboards.[728] Fifteen of the 33 floor timbers preserved on the ship were nailed to the keel with iron nails, driven through pre-drilled pilot holes; these frames were evenly distributed throughout the hull. One additional frame, FL 3, was

[728] Liphschitz and Pulak 2009, 167.

fastened to the keel with a treenail. In some cases, the pilot holes for keel nails were drilled from the inner face only partway through the molded dimension of the frame, a feature not seen on YK 14's floors.

YK 5's planking was edge-fastened entirely with regularly-spaced wooden coaks up to the first wale. Of the 22 coaks sampled for wood identification, 16 were Sycamore maple (*Acer pseudoplatanus*) while the rest were Turkey oak (*Q. cerris*).[729] The plank seams were filled with a caulking of grass and pitch. The locations of coaks, as well as some frames, were marked by scoring similar to that seen on YK 14 and 23. Coaks were also used to fasten diagonal scarfs, which are somewhat shorter than those seen on YK 14. The lack of a keel rabbet seems to have simplified the assembly process of the keel and garboard strakes: the inboard edges of the garboards abutted the vertical port and starboard faces of the keel, and were fastened to the keel only with wooden coaks. This may have resulted in a wetter bilge, since there was no longer a 'gutter' on either side of the keel for the water to collect in, but this design change seems to have simplified the hull construction process and perhaps also reduced leakage and rot between the garboard and keel seam. YK 5's hull planking also displayed many features similar to that seen on YK 14, such as a series of caulked holes in the preserved end of the hull which may have been related to the fastening a temporary frame or a floor timber which was later moved, and caulking fibers found in nail holes had clearly been wrapped around the shanks of iron nails below their heads.

[729] Liphschitz and Pulak 2009, 167.

Mortises in three floor timbers over the keel located at the center of the ship (FL 17, 20, and 22) indicate the position of the mast step, which must have been at least 1.35 m long. A single mortise over the keel area of FL 34 was likely for a stanchion used to support a through-beam and perhaps a partial deck. A 14.5 cm-long end of a single through-beam, was discovered in situ in a cut aperture in the highest surviving plank, PS 13, amidships between frames FL 17 and F 18 (see Chapter III). The through-beam was about 7.65 x 7.1 cm in cross section at the hull planking and cut with an I-shaped notch; no fasteners were used to hold the through-beam in place other than the slot or aperture cut into a plank of strake PS 13. Based on the location of this through-beam in the area of the mast step, it is likely that it served as a mast-partner beam. Presumably, other through-beams were present in the upper section of the hull elsewhere in the ship, but no evidence for these timbers survives.

The methods used to build YK 5 were nearly identical to those seen on YK 14; it is a 'mixed-construction' hull, shell-built to the first wale and shaped around frames thereafter. The main differences lie in the change in hull shape—YK 5 is a broader-beamed ship with flat floors—and in the abandonment of the keel rabbet in YK 5' lower hull. Other minor differences include the different numbers and locations of through-beams and the slightly different shapes for scarf ends and limber holes. YK 5's construction is notable in that it is much closer to that of the Serçe Limanı ship in terms of hull shape and standardization in the shape of frame timbers. These similarities suggest that the Serçe Limanı ship's framing may have antecedents in the mixed-construction hulls from Yenikapı, which were probably products of a local shipbuilding industry.

YK 24

YK 24 is the smallest and most poorly preserved of the ships documented by INA at Yenikapı. YK 24 was found to the south of YK 5 in sandy deposits dated to the tenth century C. E. About 15% of the original hull was preserved in an area of about 5 x 3.5 m, with many of the ship's disarticulated timbers, including an endpost and a mast step (**Figure 7.8**). The hull was probably about eight meters long and 2.5 m in beam. It is unclear how the vessel sank, although loss in a storm or abandonment as a derelict are both possible scenarios. YK 24 was a single-masted cargo or fishing vessel, probably designed for local use. It was quite old when it sank, judging from a number of repair pieces in the ship's hull. Like YK 5, YK 24 was built with planking edge-fastened with regularly-spaced coaks; some coak locations were clearly marked by scoring. Caulking was found between the plank seams of the hull, as well as the remains of pitch with hair deposits on the inner faces of the hull planking.

Figure 7.8: YK 24 during excavation.

YK 24's hull was flat-floored, with evidence of 14 frame stations; 11 floor timbers survived in the articulated section of the hull in addition to several disarticulated frame fragments found in the immediate area of the shipwreck. The floors resemble scaled-down versions of the floors of YK 5 or 14, but are much shorter and show less variation in their cross sectional dimensions. Molded dimensions of the floor timbers range from 6.5 to 11.7 cm, with an average maximum molded dimension of 9.7 cm; sided dimensions range from 4.6 to 6.7 cm, with an average maximum sided dimension of 6.1 cm. The hull was fastened with treenails as well as iron nails, and was heavily repaired; rot damage also occurred under a number of frame locations. Repairs include small planks or graving pieces that were inserted into damaged sections removed along plank seams, and the large number of nails in the hull, many of which were located in or near treenails, indicating that most were added during later repairs. A curved keel timber and two unusually-shaped blocks installed between the keel and endpost appear to be repairs as well, since they were not fastened with coaks to the hull as was the main keel timber. The curved keel timber has a transverse hole in its port and starboard faces similar to the one seen on YK 14. As with the keel of YK 5, YK 24's the main keel timbers were not rabbeted.

Caulked treenail holes were found between frame locations in the lower planking of the hull. These may have been fasteners for bilge keels or runner's along the hull's bottom, although other explanations such as temporary frames or props used during construction are also possible.[730] At least two contemporary vessels of similar size from Yenikapı (YK 6 and 7) have bilge keels in the same general area of the hull, and the transverse 'tow holes' in the keel timbers of YK 24 suggest that the vessel was designed for beaching.[731] The mast step has a single mortise for the mast's heel cut in its inner face and a crenellated bottom so it could be notched over floor timbers. One end of the mast step is damaged, but the preserved end shows that it was nailed to a floor timber. Strangely, no nail holes were found in the inner faces of the floors in the vessel, which suggests the floor or floors to which it was nailed were lost, or that the mast step was previously used on a different vessel.

YK 24 appears to be one of a fairly common type of small roundship from Yenikapı dating to the tenth or early eleventh centuries. Other vessels from Yenikapı with similar characteristics—eight to ten meters long, flat floored, built with coaks and relatively light in-line frames, with transverse holes in the keel for beaching—have been described in preliminary publications.[732] The names and characteristics of varieties of small sailing craft like YK 24 and similar vessels from Yenikapı are known from documentary sources.[733] The main features distinguishing these vessels from larger contemporary roundships such as YK 5 are their smaller size and scantling.

[730] C. Pulak, personal communication.
[731] Özsait-Kocabaş and Kocabaş 2008, 103, 111-13, 138-39.
[732] These include YK 6, 7, and 9 (Özsait-Kocabaş and Kocabaş 2008, 103-11, 125-39).
[733] Several names for vessels like YK 24 are mentioned in contemporary Byzantine texts. Small boats known as *sandaloi* are listed as ship's boats or support vessels for dromons in the 911 and 949 Cretan expedition inventories in the *Book of Ceremonies* (Haldon 2000a, 212, 263, n. 35). The term *sandalion* appears in the seventh century, and seems to refer to "a shallow-draught or flat-bottomed fishing boat (so named because of its similarity to a sandal)" (Haldon 2000a, 212, n. 41; see also Jal 1848, 1315). The

YK 1

YK 1 was the first shipwreck discovered on the Yenikapı site in the spring of 2005 (**Figure 7.9**). The ship's sinking is dated to the late tenth or early eleventh century based on the artifacts on board, which included a cargo of several dozen amphoras. The jars are of a piriform type commonly found on the Yenikapı site; they date from the tenth or eleventh centuries and were made in the area around Ganos (Gaziköy) on the Sea of Marmara.[734] A pair of iron anchors and a coil of rope were found in at one end of the ship, identifying the bow of the vessel. The thick layer of sand found around the wreck seemed to indicate that the ship had been at anchor, but had capsized or run aground; its remains had been completely covered by sand in a storm, probably the same storm which had sunk YK 2, 4, and 5. It appears that the ship was never relocated after its sinking, since both the anchors and the amphoras were valuable cargo, which would have been salvaged if discovered.[735] The ship may have been built early in the second half of the tenth century, and was in use for a number of years before sinking.[736]

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haliadia, also associated with fishing, was another vessel type with a fore-and-aft rig as well as oars. In the *Book of Ceremonies* inventory from 911, four sailors are required for each *sandalion*/skiff, and "Each skiff should have its mast, yard, and four oars, and a steering oar." (Haldon 2000a, 212). Makris (2002, 93) states that the term *sandalion* was used to "cover everything from rowboats to small ships." A wide range of names for commercial vessel types have been preserved in Byzantine documents, but it is often impossible to match ship types mentioned in documents to actual shipwrecks due to vague categories and changing definitions of vessel types over time (Müller-Wiener 1994, 18; see also Makris 2002, 93; Hocker 2004a, 3-4; Pryor and Jeffreys 2006, 164-73).

[734] Günsenin 2009, 147, 149-50; see also Pulak 2007a, 208.

[735] Pulak 2007a, 203, 208. The *Rhodian Sea Law* specifically mentions penalties for the theft of anchors, one indication of the value of these items of ship's equipment (see Ashburner 1976, 77-8). Extensive wear and damage to many of the amphoras from the Serçe Limanı ship (many of which were the same piriform amphora type as those from YK 1) indicate that they had been in use for many years (van Doorninck 1989, 254-46; 2002a, 903; see also Günsenin 2009, 150). Even if the contents of the YK 1 amphoras (probably wine) were contaminated by sea water, the containers themselves were apparently still valuable.

[736] Liphschitz and Pulak 2009, 166.

Figure 7.9: YK 1 during excavation in July 2005. Note the anchor in the foreground and the disarticulated keel timber at lower right.

The surviving section of YK 1's hull was about 6.5 x 3 m long; the ship itself was probably about 10 meters long and approximately 3.5 meters in beam.[737] The amphora cargo had covered most of the ship's surviving hull. Unusually, the starboard side of the ship from the turn of the bilge to the caprail was preserved; the amphora cargo appears to have shifted as the ship sank, and formed a protective layer over the surviving hull timbers. The bottom of the hull was completely lost, aside from the main keel timber and

[737] Pulak 2007a, 211.

one floor timber from an end of the ship.[738] Some of the ship's equipment, including toggles for the running rigging and a coil of rope in the bow, were found with the wreck, as well as small objects that may have been cargo or personal possessions of the crew. The surviving hull planking was edge-fastened with regularly-spaced coaks from the turn of the bilge to below the first wale; edge fasteners on the port and starboard faces of the keel timbers showed that the ship was also edge-fastened across the bottom of the hull as well. Score marks were found on the hull planking delineating the locations of some of the frames. Plank seams were caulked with grass and pine pitch, and several repair planks were evident in the hull planking.

YK 1 was built using techniques very similar to those used to construct YK 5, 14, and 24. YK 1's keel was rectangular in section, with rounded outboard edges, like those of YK 5 and 24, and had a pair of transverse 'tow holes' cut through the port and starboard faces of the timber, YK 1's keel is rockered rather than straight as on these other vessels, indicating a more rounded hull. The ship's pattern of framing is similar to that of YK 5 and 14, with in-line frames and futtocks; the original futtocks and floor ends preserved in YK 1 have similar dimensions to those of YK 5. Preserved first futtocks were 122-159 cm long and had molded dimensions ranging from 4.8 to 12.3 cm, with an average maximum dimension of 11.3 cm, and sided dimensions ranging from 5.8 to 8.7 cm, with an average maximum dimension of 8.2 cm. These timbers are both longer and heavier than those used at the same locations in the hull of YK 14.

[738] This ship is incorrectly reported as having a preserved bilge keel in Pomey et al. 2012 (290, Table 3).

The ‘long arm’ ends of floors, which had broken off just above the turn of the bilge, had molded dimensions ranging from 4.5 to 10.7 cm, with an average maximum dimension of 9.5 cm, and sided dimensions ranging from 2.6 to 8.7 cm, with an average maximum dimension of 6.6 cm. The wales were of similar dimensions (7.5-12 cm wide, and 2.3-7.2 cm thick) and had been shaped using similar methods to wale PS 13 on YK 14, as shown by evidence of charring, and cut depressions and raised areas at some frame locations. Coaks were driven into the wales in several locations to secure the diagonal scarf ends of hull planks. Between the futtock timbers were six small plank pieces embedded in pitch; they appear to have been used as ceiling planks, filling gaps between the frames just above the turn of the bilge. A single stringer, 624 cm long, 6.9-8.9 cm wide, and 2.2-4.2 cm thick, was installed in the hull at the waterline; its beveled edges, location, and relatively small dimensions closely resemble the features of stringer ST-1 on YK 14.

At some time during the ship’s career, YK 1 was subjected to a major overhaul, in which the sides of the ship were raised by about 60 cm to increase the vessel’s freeboard (**Figure 7.10**). When the ship was originally constructed, the surviving section of hull was reinforced with at least 24 futtocks, 16 of which were found still attached to the remaining hull. To increase the height of the ship’s bulwarks, 12 more roughly-shaped secondary futtocks or top timbers were added in between the original futtocks and fastened with iron nails in order to support the new strakes.[739] These timbers were made in two lengths: 'long secondary' futtocks (1.78-1.92 m long) and 'short secondary' futtocks (1.21-1.63 m long). Two futtocks had grooves cut into their edges for a removable plank, a feature probably used to accommodate a loading ramp. As with YK 5, 14, and 24, all of the original hull timbers used in the ship's construction as well as the ship's secondary futtocks were made from Turkey oak (*Q. cerris*). All of the sampled treenails and coaks from the ship were also made from this oak species.[740] However, the planking and new caprail used to extend the ship's sides were made from a variety of less rigid, non-oak species such as Oriental plane (*Platanus orientalis*), Turkish pine (*Pinus brutia*), and poplar (*Populus nigra* or *P. alba*). For the overhaul, the shipwrights probably used whatever timbers were in the immediate area where the repairs were taking place. A large number of iron nails were likely added to the hull at this time as well. Many of these nails were driven into or near treenails, an indication that they were likely for repairs. These were used to reinforce the treenails fastening the planking to the frames, which would have loosened over time.[741]

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[739] Pulak 2007a, 208-11; see also Liphschitz and Pulak 2009, 166-67.
[740] Liphschitz and Pulak 2009, 166-67.
[741] Liphschitz and Pulak 2009, 167.

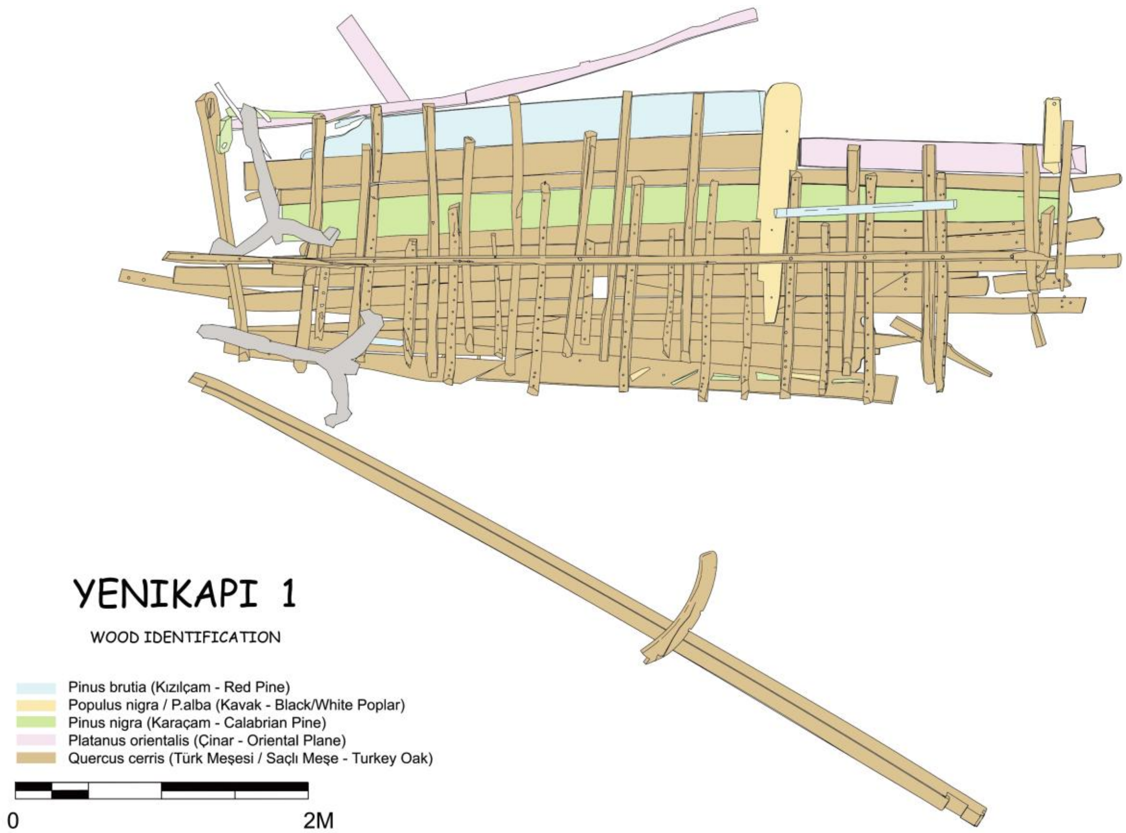

Figure 7.10: Plan of YK 1 shipwreck, color-coded by wood type; while the original section of the hull was built with Turkey oak, the upper strakes, which were installed during a later overhaul of the ship, were made from a variety of wood species (Plan by S. Matthews and R. Ingram).

Other modifications may have also occurred at this time. An approximately 15 x 13 cm hole, with finished plank ends on either side, was found in the planking amidships in strake S-6, above the first wale. This was likely the position for a mast-partner beam. However, the planks adjacent to the through-beam aperture suggest that the position of the mast partner may have been changed slightly; the forward plank (S 6/10) is little more than a diagonal scarf end, while a short plank with butt scarfs fastened only with iron nails aft of the through-beam aperture (S 6/7-9) appears to be a repair plank. Perhaps most of the original plank, S 6/10, was removed and replaced with S 6/7-9, a modification which could have been related to the replacement of the mast partner beam. A series of holes drilled at an angle were found in the original wales between frames, plugged either with caulking or treenails, or wooden plugs on either end. The reason for these plugged holes is unclear, but it is possible that at least some were holes for fasteners used in securing through-beams similar to those seen in wale PS 13 on YK 14. However, based on their presence and numbers in all of the original wales (five each in Wales 1 and 2, two in Wale 3, and three in Wale 4), it is highly doubtful that most or all of them were used for this purpose.

Other Roundship Types from Yenikapı

In addition to the six roundships documented by INA, preliminary reports on a number of others from Yenikapı have been published by Istanbul University's Department of Conservation of Marine Archaeological Objects. A number of these shipwrecks have similar features to roundships studied by INA and have already been mentioned; they are flat-floored vessels with in-line framing and planking edge-fastened with coaks.[742] However, several possess distinctive features not found on the shipwrecks discussed above. The shipwrecks studied by Istanbul University have been divided in preliminary publications into several types, including 'local trading vessels', small cargo ships or fishing boats about 8-9 m long (YK 6, 9, and 12); 'medium-sized cargo vessels', classified as 10-12 m long (YK 7, 8, and 18) and large cargo carriers 17-19 m long (YK

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742 Several of the tenth- or eleventh-century roundships from Yenikapı appear to have been built with futtocks placed adjacent to, rather than in line with, floor timbers, including YK 3 and YK 18 (Özsait-Kocabaş and Kocabaş 2008, 140-42, 152-54).

3, 15, and 17).[743] These broad types could be further divided at a later stage of study, since significant differences in hull form and construction are apparent even among vessels of similar sizes, and the size estimates of the ships' hulls could be refined by further research.

YK 12

YK 12, which has been dated by the excavators to the ninth or tenth centuries C.E., was a small coastal trader with an estimated original length of 8.5 m and beam of 2.8 m.[744] This vessel is one of the few ships from the site discovered with an apparently full cargo of amphoras, indicating its loss in a storm similar to that which sank YK 14. The cargo included Günsenin 1 amphoras, probably filled with wine, as well as objects in a bulkhead compartment area close to the stern of the ship, including a ceramic brazier, galley wares, and a basket of cherries.[745] The construction of the vessel itself closely resembles that of YK 14; it was built with regularly-spaced coaks to the first wale, light, in-line framing very similar to that of YK 14, and a pair of bulkheads secured by grooved futtocks similar to those on YK 14. However, it was a smaller ship with a more

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[743] Kocabaş and Özsait-Kocabaş 2010, 115; see also Kocabaş 2008. The 'medium-sized cargo carrier' category could be enlarged to include ships up to 15 meters in length to include vessels such as YK 5 and 14.

[744] Özsait-Kocabaş and Kocabaş 2008, 112-14; see also Özsait-Kocabaş 2012, 115, n. 1. The date of the vessel was determined by three calibrated radiocarbon dates ranging between 672 and 870 and stylistic dating of the amphoras. F. H. van Doorninck believes that the amphora cargo of the ship, which were identified as 'Ganos type' amphoras by Özsait-Kocabaş and Kocabaş (2008, 112) are incorrectly identified and are in fact a different variety of Günsenin 1 amphoras. According to van Doorninck, this type has parallels from the Black Sea dating to later in the tenth century based on stamps of the emperors and Nicephoros II Phocas (963-969) and John Tzimiskes (969-976) (Parshina 2001, 105, 110, 112). This type also resembles Hayes' Type 52 amphora from Saraçhane, which was found in early tenth-century deposits but may be intrusive (F. H. van Doorninck, personal communication, February 2013; see also Hayes 1992, 2:70-1, 73, 75).

[745] Özsait-Kocabaş and Kocabaş 2008, 114-17; 2010, 30; see also Asal 2010, 159, Fig. 12-5.

rounded hull built mostly of chestnut (*Castanea* sp.) and with a smaller bulkhead area.[746] The construction sequence of the vessel was similar to YK 14 as well; Özsait-Kocabaş states that framing was fastened in the hull after the hull planking was constructed to the ship's waterline.[747] Unlike YK 14, most of the interior of YK 12 was covered in ceiling planking, which was nailed to the frames in some locations.[748] YK 12 is also significant for having an elongated mast step preserved with two mortises in its inner face (see Chapter V).[749]

Larger Roundships from Yenikapı: YK 3, 17, 22, and 29

Although most of the shipwrecks from the Yenikapı site ranged in size from 8-15 meters, several were larger. YK 22, the largest shipwreck from the site, dates to the sixth century and is likely representative of the largest type of *annona* vessels used in the period.[750] After the seventh century, there are a few examples of larger vessels as well, although these ships are still quite small by the standards of the early Imperial period.[751] YK 3, dated to the tenth or eleventh century, has an estimated length of 18 m and beam

[746] Özsait-Kocabaş and Kocabaş 2008, 115-24; see also I. Kocabaş 2012a, 115-18.
[747] Özsait-Kocabaş 2012, 118.
[748] Perhaps on YK 14 the spaces between frames were filled with sticks or poles, as was found on other ships at the site such as YK 9 (Özsait-Kocabaş and Kocabaş 2008, 125). The use of dunnage is another possibility. Seeds from thorny burnet (*Sarcopoterium spinosum*), which were found inside amphoras from the Yassıada seventh-century shipwreck may have originated from dunnage (van Doorninck 1989, 252); Gorham (2000, 135-36) suggests a similar origin for thorny burnet seeds in amphoras from the Bozburun shipwreck. This shrub was used for dunnage on the Uluburun shipwreck as well as later shipwrecks from the Israeli coast dating to the fourth century C.E. (Haldane 1993, 356; see also Pulak 2000, 140-41, and Rosen et al. 2009, especially p. 170-71, which mention other species of dunnage material found on Mediterranean shipwrecks).
[749] Özsait-Kocabaş and Kocabaş 2008, 115-16.
[750] Kocabaş 2012a, 109.
[751] Shipwreck cargoes and textual references from the sixth century indicate that ships of 200-300 tons were still in use in the sixth and early seventh centuries (van Doorninck 1972, 139; 2002a, 899).

of 6 m. The ship was built with quite heavy components, such as the large waterline wale (approximately 18 cm wide and 10 cm thick), and its 3 cm-thick ceiling planking, while other timbers, such as the ship's frames, are of similar dimensions to those on other tenth-century ships from Yenikapı.[752] The vessel was found full of construction rubble.[753] Another unusual feature of YK 3 are coak joints fastening the inboard edge of the wale to the previous strake, a feature not found on any of the Yenikapı shipwrecks excavated by INA.[754]

The size of these ships corresponds quite well with those of other post-seventh-century vessels discovered in the Mediterranean. Five excavated shipwrecks from Tantura Lagoon dating from the fifth to ninth centuries have reconstructed lengths from 12-23 meters; the largest, Tantura B, may be a rowed vessel, and, as such, longer than typical merchant ships.[755] Excavated off the southern coast of France, the tenth-century Agay A ship is estimated to have been between 20-25 meters in length, while the contemporary Bataiguier ship's estimated original length is around 20 meters.[756] These sizes also correspond well with the ship capacities mentioned in monastic documents of the eleventh and twelfth centuries.[757]

[752] Özsait-Kocabaş and Kocabaş 2008, 157-63. The floor timbers are described as having sided dimensions of 7-12 cm and molded dimensions of 10-12 cm, which is comparable to those on a ship such as YK 5.
[753] Özsait-Kocabaş and Kocabaş 2008, 152.
[754] Özsait-Kocabaş and Kocabaş 2008, 152.
[755] Pomey et al. 2012, 259-63, 269-71; see also Khalilieh 2005, 314, 319.
[756] Rieth 2008, 55l; see also Joncheray 2007a; 2007b.
[757] Harvey 1989, 238-41.

YK 17 is another large, heavily built, and relatively flat-floored vessel tentatively dated to the eighth or ninth century.[758] The preserved section of the hull is 8.2 m long and approximately 2.25 m wide, representing part of one side of the hull from the garboard up to the turn of the bilge.[759] The vessel's original length is estimated at 15-18 m, with an original beam of 5 m.[760] Although the keel timber is missing, the location of the keel was apparent from the position of limber holes on the preserved frames, which consist of alternating floors and paired half-frames.[761] The vessel's plank seams were caulked.[762] The ship was constructed with several heavy stringers, 6 to 9 cm thick, as well as a large wale at the turn of the bilge, 30 cm wide and 9 cm thick, with clear charring on the inner face. A second, smaller wale, approximately 12 cm wide and 5 cm thick, was installed higher in the hull.[763]

YK 17 is significant for the absence of edge fasteners in its hull planking. Four other shipwrecks from the Yenikapı site are reported to have been built without the use of edge fasteners on planking as well, including YK 27, dating to the late seventh to ninth century, and YK 29, dating to the eighth century; however, little additional information is currently available on these ships.[764] The heavy wales at the bilge area of YK 17 are unusual on ships from Yenikapı. The design is reminiscent of heavy chine wales on the

[758] Özsait-Kocabaş and Kocabaş 2008, 168; see also Türkmenoğlu 2012, 121-22.
[759] Özsait-Kocabaş and Kocabaş 2008, 168-70.
[760] Özsait-Kocabaş and Kocabaş 2008, 168; see also Türkmenoğlu 2012, 122.
[761] Türkmenoğlu 2012, 123.
[762] Türkmenoğlu 2012, 124.
[763] Özsait-Kocabaş and Kocabaş 2008, 174.
[764] Özsait-Kocabaş and Kocabaş 2008, 168; 2012, 110; O. Köyağasıoğlu, personal communication, May 2013.

Tantura B ship and early Imperial-era barges from the Rhône and Saône rivers in France and elsewhere in Europe.[765] The use of heavy wales in the turn of the bilge also has parallels on the sixth-century vessel from Pantano Longarini,[766] and the contemporaneous Dor 2001/1 shipwreck, which will be discussed below. Either the use of a 'bottom-based' construction method, perhaps using temporary frames or cleats, or, a frame-based construction method could explain the lack of edge fasteners on YK 17.

Longships from Yenikapı

Six shipwrecks from Yenikapı are rowed vessels or galleys, the first shipwrecks of this kind discovered from the Byzantine period. The galleys appear to date from the eighth to the tenth centuries C.E.[767] Although longships could have served as either merchant vessels or warships in the ancient and medieval world, the estimated length-to-beam ratio of the Yenikapı galleys as well as evidence for large numbers of rowing benches in the hull of YK 4 indicate a probable function as light warships.[768] In emperor Leo VI's *Taktika*, dating to around 900 C.E., a chapter on naval warfare includes references to *galeai* in naval fleets. These warships were lighter than the larger dromons, the main warships of the Byzantine fleet, and seem to have been deployed for scouting,

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[765] Kahanov et al. 2004, 121-22; Guyon and Rieth 2009, 157, 161; Hocker 2004b, 67-72; Long et al. 2009, 305-7.
[766] Throckmorton 1973, 254-59.
[767] Approximate dates for four of the galleys are published. YK 2 and YK 4 both appear to have sunk in the same late tenth-century storm that sank many of the vessels at the site, although YK 4 was a significantly older than YK 2 based on the repairs to the hull (Pulak 2007a, 203, 213-14). Timbers from galleys YK 13 and 16 have been carbon-14-dated to 690-890 C.E. and 720-742 C.E., respectively, although no information is provided on the number of samples analyzed or from which hull timbers they were taken (Kocabaş 2012a, 108, 112, n. 3-4).
[768] Casson 1995, 157-68; see also Pulak 2007a, 214-15.

dispatching messages, guarding coastlines, raiding, and other duties.[769] Galleys were sailed as well as rowed; although larger dromons had two masts, smaller galleys such as YK 2 and 4 probably would have been equipped with a single mast with a lateen rig.[770]

Two of the Yenikapı galleys, YK 2 and 4, were documented by INA (**Figure 7.11**). Although there are major differences in function, design, and construction features to the Yenikapı roundships, they do offer some useful parallels in terms of construction and design methods. Both YK 2 and 4 likely sank in the same storm that appears to have sunk YK 5 and a number of other vessels on the site in the late tenth century.[771] Both vessels were built using very similar materials and construction techniques, and are similar in age; artifacts in the layers of both shipwrecks are dated to the later tenth century.

[769] Dennis 2010, 507; see also Pryor and Jeffreys 2006, 190-91. Leo's *Taktika* describes the uses of *galeai*: "In addition, you will outfit smaller dromons, very fast ones, like those called galleys or *monoremes*, swift and light, which you can use for scouting and other operations requiring speed." Admirals are also instructed to position "scouts… at some distance, whether by land or sea" to avoid surprise by an enemy (Dennis 2010, 507, 517). Haldon (2000a, 218) notes references to *galeai* being left behind to patrol specific coastal regions while the main battle fleet was deployed to Crete in 911. They were also described in the same text as being used to scout enemy coastlines for signs of naval activity (Haldon 2000a, 208, n. 24). 'Dromon' seems to be used as a generic term for warship by the tenth century, although it had a more specific meaning in earlier periods; and other terms are also used, which seem to refer to more specific types of dromons were also used (Dennis 2010, 505-7, 521, 533; see also Pryor and Jeffreys 2006, 169-73, 191-92). Pryor and Jeffreys define the dromons of the sixth to ninth century as fully decked, lateen-rigged galleys with spurs rather than waterline rams. (Pryor and Jeffreys 2006, 124-29).
[770] Pryor and Jeffreys 2006, 205, Fig. 20, 238-42; see also Pulak 2007a, 213.
[771] Pulak 2007a, 211.

Figure 7.11: YK 2, April 2006.

Both galleys were built with long, wide planks of European Black Pine (*Pinus nigra*); these timbers typically ranged up to 20-40 cm wide, approximately 2-3 cm thick, and could be up to 10-11 meters long.[772] This timber was far superior to any timber seen in the post-seventh-century merchant ships at Yenikapı. Planks of these dimensions may have been specifically selected to minimize the number of plank seams and scarfs and for their strength, an important consideration in a longship's hull, where hogging and sagging cause major strains on the structure of the ship.[773] On both vessels, the keel was rabbeted and fastened to the garboards with regularly-spaced iron nails. Plank seams were caulked, and planks were edge-fastened with coaks more widely spaced and less regular than those in the hulls of contemporary roundships from Yenikapı. Long S-scarf ends were used in the hull planking; as on YK 14, these were usually fastened with coaks.

The framing on both ships was very light, with molded and sided dimensions typically between 4 and 6 cm; they were arranged as alternating floors and paired half frames, similar to those of roundships from the site pre-dating the tenth century. About 80% of the framing on YK 2 and 85% on YK 4 consists of Oriental plane (*Platanus orientalis*); YK 4's keel and keelson were also made from this wood species.[774] Although a

[772] Liphschitz and Pulak 2009, 168-69.
[773] Liphschitz and Pulak 2009, 171.
[774] Liphschitz and Pulak 2009, 168-69. The remaining frames on YK 2 are of European elm (*Ulmus campestris*) (Liphschitz and Pulak 2009, 168-69). On YK 4, a number of repair floors and half-frames in the turn of the bilge area were made from European ash (*Fraxinus excelsior*), Sycamore maple (*Acer pseudoplatanus*), Turkey oak (*Q. cerris*), Tamarisk (*Tamarix* (X5)), and European black pine (*Pinus nigra*) with treenails of several species, primarily Oriental plane. Several of the largest repair frames are

relatively soft wood, Oriental plane may have been selected for its lightness, an important consideration in galley construction, and perhaps its ready availability.[775] Frames were attached to planking with both treenails (primarily of Turkey oak) and iron nails, and hull planks were edge-fastened together with coaks of Turkey oak, except for the garboard strakes, which were fastened to the keel only with closely-spaced nails.[776] On YK 2, four wide, flat stringers, also of flexible European black pine, were nailed to the inner faces of the frames. These timbers may have provided some additional internal support, but were quite thin, having an average thickness of only 2.6 cm. A number of long timbers of Oriental plane with notches and nail holes on the ends were found at one end of the shipwreck; these were likely dislodged rowers' benches. On YK 4, the spaces between rowers are provided by nine bench notches cut into the first of three wales in the hull, and remains of a sheer strake with oarports allow the spacing of the rowers to be reconstructed: the ship likely had 25 rowers per side, spaced approximately 95 cm apart.[777]

The construction methods used to build the galleys are still under study, but a combination of shell- and skeleton-building methods were noted during the excavation.

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floor timbers which may have been located around the mast's probable location (Liphschitz and Pulak 2009, 169).

[775] Liphschitz and Pulak 2009, 171. Braudel (1995, 1:142) notes that the seventeenth-century author Bartolomeo Crescentio Romano (1607, 4) describes Oriental plane as "an excellent wood that behaves particularly well in water." Ancient authors tend to describe Oriental plane as being used for "bentwood" (wales or compass timber?), which, along with elm, is described as "tough and strong", although "That made of plane-wood is worst, since it soon decays" (*Hist. Pl.* V.VII.2-3; For the word "bentwood" in this passage, see trans. Hort 1999, 457, n. 5).

[776] Liphschitz and Pulak 2009, 169-70.

[777] In the hull of galley YK 16, excavated by Istanbul University, "About sixteen" notches cut for the ends of rowers' benches were found in the upper face of the first wale, with similar spacing to those found on YK 4 (Kocabaş 2012b, 315-16).

Signs of shell-first construction include the coak joints in many plank edges, some of which were marked by scoring; adzed depressions and score marks at frame locations; and plugged nail and treenail holes in the planking between frame locations which may have been used for temporary frames. Other signs show evidence for pre-planned construction. Saw marks at regular intervals of 22-23 cm were cut into the inner face of the keel to mark frame stations, while the notches cut under some frame locations discussed in Chapter III indicate that frames were likely installed to aid in fastening the wales to the hull.

The construction features and scantling of the different galleys are consistent in terms of dimensions and hull shape. These ships were clearly built to a high standard with superior timber and with more abundant materials (iron nails, etc.) to what was used for most of the contemporaneous Yenikapı roundships. Many of the techniques used in the construction of the Yenikapı galleys are traditional for Mediterranean seagoing ships, including the use of planking edge fasteners, the long S-scarfs on the hull planking, and the framing pattern of alternating floors and paired half-frames, which, by the tenth century, is no longer found on the cargo vessels from Yenikapı. Other aspects of the galley's construction are more technologically advanced than those of contemporaneous roundships from the same site, such as the use of a keelson running the full length of the hull.[778] Further study is required to understand the exact methods used in constructing these vessels, but it is evident that, despite the differences in materials and functions,

[778] A large section of the keelson of YK16 was discovered in-situ (Özsait-Kocabaş and Kocabaş 2008, 177, Fig. 88a).

they were produced in the same shipbuilding tradition as most, if not all, of the Yenikapı roundships. If ship construction had been simplified in some respects in merchant vessels, the high quality of the construction of the galleys shows that shipwrights of the period were capable of building highly sophisticated and technologically advanced vessels when necessary and when the resources were available, while still incorporating some apparently archaic features in these vessels that had been used in ship construction since antiquity. Such varied and technologically sophisticated adaptations of traditional ship construction methods seem to be typical of the Byzantine shipbuilding industry represented by the Yenikapı shipwrecks.

Summary of the Characteristics of the Yenikapı Shipwrecks

The Yenikapı shipwrecks discussed here share a number of common characteristics. Although several of the Yenikapı ships were built without edge fasteners, these vessels are only a small percentage of the total from the Yenikapı site, and also seem to occur only in a period roughly dated to the eighth and ninth centuries. The methods used in their construction were probably not the dominant ones around Constantinople, particularly in the tenth century, and they did not immediately supersede coak-built, mixed construction (but essentially shell-first in principle) hulls such as YK 14.

The Yenikapı shipwrecks appear to represent the last stage of edge-fastened, shell-built hulls in the eastern Mediterranean. The earliest shipwrecks from the site are remarkably similar in design to most other Late Roman and early Byzantine seagoing ships found throughout the Mediterranean. Ships such as YK 11 display virtually all of the major characteristics of Greco-Roman seagoing ships, at least in the modified form typical of the Late Roman period: unpegged mortise-and-tenon edge joinery to the waterline, framing patterns consisting of alternating floors and paired half-frames, edge-fastened diagonal or S-scarfs in the hull planking, and, frequently, a 'wine-glass'-shaped cross section to the hull. After the seventh century, significant changes in hull construction become more apparent. The ninth-century ship YK 23 seem to retain many older features, such as the traditional hull shape and framing pattern as well as the use of edge fasteners, but also shows signs of change, in the replacement of mortise-and-tenon joints with coaks.

The regular use of caulking in plank seams is another important characteristic of the Yenikapı shipwrecks, and is likely an indication of a wider change in Late Roman and Byzantine period ship construction. Once they had been immersed for a time, the tenons in pegged mortise-and-tenon edge-joints such as those used in the Kyrenia ship swelled, fastening the ship's plank seams together so tightly that only an outer layer of pitch or other protective layer, such as tarred canvas and lead sheathing fastened with tacks, could keep the hull sufficiently waterproof. Unpegged mortise-and-tenon joints, on the other hand, only hold the seam together by friction and by frame fasteners in individual planks and strakes. For this reason, the use of caulking in plank seams was probably standard in Late Roman and Early Byzantine-era edge-fastened hulls by the sixth or seventh century, if not earlier. Nautical archaeologists have often assumed that edge fasteners of any kind preclude the use of plank seam caulking, since driving caulking can damage the edge fasteners. Sometimes its presence in plank seams on Late Roman anf Byzantine shipwrecks has been explained as due to later repairs or a characteristic of skeleton-first construction. While both conclusions are plausible and doubtless correct in some instances, they do not account for the possible use of laid-caulking or the decreased importance of edge fasteners to the contribution of hull strength in later ships; caulking could be added during construction, or caulkers may simply have been indifferent to damaging edge fasteners. This assumption may also be based on the generally poor preservation of caulking material on most excavated shipwrecks and the assumption that later mortise-and-tenon-built hulls were constructed using the same methods as earlier ships. The presence of caulking in plank seams on the Yenikapı ships seems to indicate that the use of caulking, whether laid or driven, was a standard practice in edge-fastened hulls by the Byzantine period.[779]

Features of many of the Yenikapı ships, such as flat floors or the lack of planking edge fasteners on vessels such as YK 17, may be evidence of experimentation in new vessel

[779] For example, the seventh-century Yassıada ship was assumed to have been waterproofed only with an outer layer of pitch and not with applied or driven caulking between the plank seams; a caulking iron found on board was thought to be for repairs only (Bass and van Doorninck 1982, 248-49; Steffy 1982a, 72). Caulking material has been found on the Port Vendres I ship, Dramont E (ships built with pegged mortise-and-tenon joints), the Point Berteau wreck, Tantura A, B, F, and Dor 2001/1 (ships lacking edge-fastened planking), and St. Gervais 2 (a ship with only a few identified mortise-and-tenon joints), in addition to earlier ‘Romano-Celtic’ and laced-construction vessels found throughout Europe (Liou 1974, 422, Fig. 7; Rival 1991, 276; Jézégou 1992, 36; Santamaria 1995, 149-50; Steffy 1999, 403; Rieth et al. 2001, 83; Kahanov et al. 2004, 117, 121). Seam caulking was found on all eight of the Yenikapı ships under study by Cemal Pulak and the Institute of Nautical Archaeology. In published preliminary reports, seam caulking is reported in a number of the Yenikapı wrecks studied by Istanbul University (Özsait-Kocabaş and Kocabaş 2008, 103, 125, 132, 135, 157, 171).

designs in this period, or they could have simply copied or have been influenced by hull designs seen mainly in barges or river craft. After the eighth century, relatively flat-floored vessels built of oak, with planking edges fastened with coaks, and with in-line framing become the dominant roundship type at Yenikapı. Small, shallow-draft vessels requiring minimal harbor facilities were clearly common at Yenikapı. The Yenikapı shipwrecks seem to confirm earlier observations on the decrease of ship sizes in this period, although it is possible that any larger ships in use after the seventh century would have unloaded in the Julian Harbor to the east, which may have been more active and better maintained.[780]

Changes in ship construction in the sixth and seventh centuries seem to have been quite rapid in comparison to earlier periods. However, in the Sea of Marmara region there does not appear to be a clear break with the older Mediterranean shell-first construction tradition. YK 14 is likely one of the earlier shipwrecks representing a final stage of edge-fastened hull construction. It still shows some more archaic features besides its edge-fastened planking (see Chapter IV), particularly in the use of a rabbeted keel, which gives the hull a sort of vestigial 'wine-glass' shape reminiscent of earlier ships such as YK 11 and YK 23. But the ship's nearly flat-floored construction and resulting shallow draft seem to be suited for beaching or sailing in shallow waters near shore—good

[780] Textual references to the use of the Theodosian Harbor cease after the late seventh century, while references to the Julian or Sophian Harbor (including occasional dredging operations) continued to be recorded (Berger 1993, 467-77; see also Magdalino 2000a, 215).

characteristics for a coaster—and its relatively narrow hull shape likely resulted in a ship which handled well.

The changes in design between YK 14 and the slightly later tenth-century vessels such as YK 1, 5, and 24 are also instructive. All three of the later ships have abandoned the rabbeted keel configuration; the abandonment of keel rabbets made it easier for using coaks as edge fasteners, and also gives the vessel a simpler, flat-floored, shallow-draft design. These roundships have even flatter floors than YK 14, a sharper turn of the bilge, and wider hulls. The cross section of YK 5 and other tenth-century roundships from the site are very similar to that of the skeleton-first Serçe Limanı ship, and the dimensions of the hull are quite similar as well. The switch to in-line framing in the Yenikapı ships in the ninth century may also be the result of attempts to increase the efficiency of construction by producing more standardized, easily replicated floor timbers as well as maximizing cargo space. The trend in Byzantine shipbuilding towards increased efficiency and economy noted by van Doorninck and Steffy in the hulls of the Yassıada ships is also apparent in the tenth-century Yenikapı ships, in perhaps an even more extreme form.[781] Cheaper treenails replaced iron nails as the primary fasteners in

[781] Bass and van Doorninck 1982, 312; Steffy 1982a, 82-3; 1994, 85; van Doorninck 2002a, 900. Steffy (1994, 80) emphasizes, for example, the use of shorter iron nails in the seventh century Yassıada hull rather than clenched copper nails like those used in earlier Mediterranean ships. Such a change could be an early cost-cutting measure. Hocker (2004b, 81) notes the large cost or iron fasteners in some types of ship construction, although he is citing later vessels from northern Europe built using clinker construction, which requires more iron fasteners than were used in Late Roman and early Byzantine vessels. The decreased use of iron nails in the construction of at least some types of vessels in the Middle Byzantine period may have been based on economic reasons. Access to abundant supplies of iron may have become more difficult beginning in the seventh century, possibly due to wars, political turmoil, and loss of territory in the period, although exploitation of iron sources must have continued (Vryonis 1962, 4, 8, 11-

roundship hulls, coaks had replaced the (arguably) more complex mortise-and-tenon joints, and frame shapes were simplified. The disappearance of pine in the construction of the Yenikapı roundships in favor of oak may indicate a greater reliance on local timber resources (i.e., another economizing measure), in spite of the perhaps mediocre quality of the timber (see Chapter VI).

Once the floor timbers of Byzantine roundships were modified or reduced to shapes that were relatively easy to replicate, as on YK 1, 5, and 24, and the upper section of the hull is already shaped around frames, it is a relatively small step to prefabricate the frames first using simple geometric methods such as those used in building the Serçe Limanı ship. The Serçe Limanı ship, as well as the next well-documented hulls of skeleton-built ships in the Mediterranean, the Culip VI and Les Sorres X ships from the Catalan coast and the Contarina 1 ship from the Po River, all dating to around C.E. 1300, were also built with flat floors.[782] Several other wrecks dating from the tenth to twelfth centuries may have also been built using frame-first methods as well.[783]

4) Other Byzantine-Era Wrecks from the Coast of Turkey, 9th-11th Centuries

The Bozburun Ship

The Bozburun ship is perhaps the closest archaeological parallel to YK 14 excavated outside of Istanbul. The shipwreck was discovered off the southwestern coast of Turkey

3, 16-7; see also Edmonson 1989, 84; Matschke 2002, 117-19). Even a relatively small rise in prices could have encouraged the building of ships with as little iron as possible.

782 Palou et al., 115-90; see also Bonino 2007. Beltrame (2009, 412), however, dates the Contarina 1 ship to the second half of the fifteenth or early sixteenth century.

783 Joncheray 2007a; 2007b; Ferroni and Meucci 1995/1996; Pomey et al. 2012, 274-77.

in a survey conducted by George Bass of INA in 1973 and excavated between 1994 and 1998.[784] The ship carried a cargo of over 970 amphoras of four main types, one of which (Bozburun Class 1) is a type widely distributed throughout the Byzantine Empire in the ninth century C.E.[785] Much of the starboard side the hull was preserved under the amphora mound from the keel to the turn of the bilge, a length of about 12 m, as well as fragmentary remains of the port side.[786] Like the seventh-century Yassıada ship, the Bozburun ship had a galley with a tiled hearth; galley ware included a set of eight individual-sized cooking pots (perhaps an indication of the size of the crew), as well as two ceramic collar stands and pottery and copper jugs.[787] A bronze steelyard, a pottery lamp, a glass vessel, iron objects, and two iron anchors were also discovered on the wreck site.[788] The shipwreck itself has been dated by dendrochronology of the oak timbers to the later ninth century; the felling date for the keel timber was placed at 874, which gives a terminus post quem date for the construction of the vessel.[789]

The Bozburun ship has been reconstructed as 14 m in length, 5 m in beam, and with a 2 m-deep hold; it had an estimated cargo capacity of about 31 tons, and may have been fully-decked.[790] The ship's hull was built almost entirely of oak planking, an oak keel and two oak transitional keel timbers, oak ceiling planks, and a combination of oak and

[784] Bass 1973; see also Hocker 1995; 1998a; 1998b.
[785] Hocker 1995, 6-8; 1998a, 14; 1998b, 4-5.
[786] Hocker 1998b, 8-9.
[787] Hocker 1998a, 14-6; 1998b, 6; see also Danis 2002.
[788] Hocker 1998a, 15; 1998b, 7.
[789] Harpster 2006, 95.
[790] Harpster 2005a, 463.

pine frames.[791] Seven of the total of 35 floors preserved were of oak and were concentrated primarily in the center of the hull, while three of the 11 surviving futtocks were also oak; the majority of the frames as well as a stringer are of pine.[792] The oak was identified as a white oak, possibly Holm oak (*Quercus ilex*), which is common in the area where the ship sank, while the pine is likely Turkish pine (*P. brutia*).[793] The ship was heavily built. The rabbeted keel and endposts have molded dimensions of 26-30 cm and sided dimensions of 14-18 cm, substantially larger than the keel timbers of YK 14.[794] Iron bolts were used in the keel and endpost timbers to secure hook scarfs as well as a probable longitudinal timber (a stemson or sternsom) at one end of the ship.[795] The 3-4 cm-thick garboard strakes were nailed in the keel rabbet with iron nails.[796] Planks were joined to form strakes with diagonal or S-scarfs, usually fastened with coaks in the manner seen on YK 14 and other ninth- and tenth-century ships from Yenikapı.[797] Ceiling planks were 2.5-3.7 cm thick and irregularly fastened, while the stringer was 5.9 and 6.5 cm thick.[798] Remnants of a wale and a badly eroded mast step were also discovered.[799] The frames themselves were large, with molded dimensions ranging between 10-13 cm to 21-3 cm on a few floor timbers amidships, and sided dimensions of 11-18 cm.[800] About half of the 35 floor timbers preserved were nailed to the keel.[801] Four

[791] Harpster 2005a, 10.
[792] Hocker 1998b, 9; see also Harpster 2005a, 10, 104-5.
[793] Hocker 1998b, 9.
[794] Harpster 2005a, 69-70, 77, 82, 92, 95.
[795] Harpster 2005a, 85-6, 89-90, 96, 350; see also Hocker 1998b, 9.
[796] Harpster 2005a, 74, 89, 95-6.
[797] Harpster 2005a, 235, 307, 313, 320, 327-8, 332, 339, 340-41.
[798] Harpster 2005a, 341-49.
[799] Harpster 2005a, 350; see also Hocker 1998b, 9.
[800] Harpster 2005a, 114, 160-61.
[801] Harpster 2005a, 439.

oak frames in the central section of the hull had scarf ends for futtocks very similar to those found on YK 14 (**Figure 7.12**); this indicates that at least some of the floor timbers in the central section of the hull were L-shaped, in-line frames, similar to the floors of YK 14.[802] The Bozburun ship is one of the earliest ships from Turkey with this feature, and the only one known outside of the Yenikapı site.

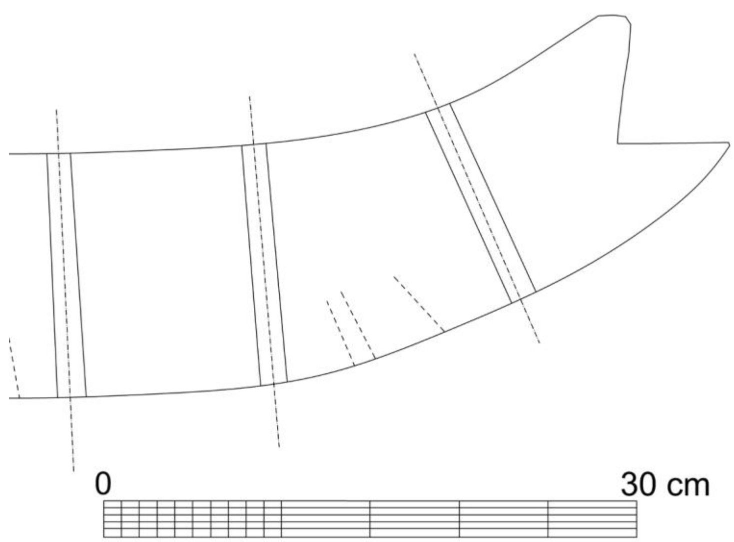

Figure 7.12: The futtock scarf at the end of Floor E on the Bozburun ship, scarfed for a futtock (After Harpster 2005b, 123, Fig. 3-31).

The form of the Bozburun ship's frames differs slightly than those of YK 14; besides the major differences in size, the Bozburun floors have a more significant flare at the keel and garboard area due to the 'wine-glass' shape of the hull; the ship resembles YK 23 in

[802] Harpster 2005a, 107-10, 115.

cross section (**Figure 7.13**).[803] Planking and oak frames were fastened together with treenails and iron nails, while the pine frames were fastened exclusively with iron nails.[804]

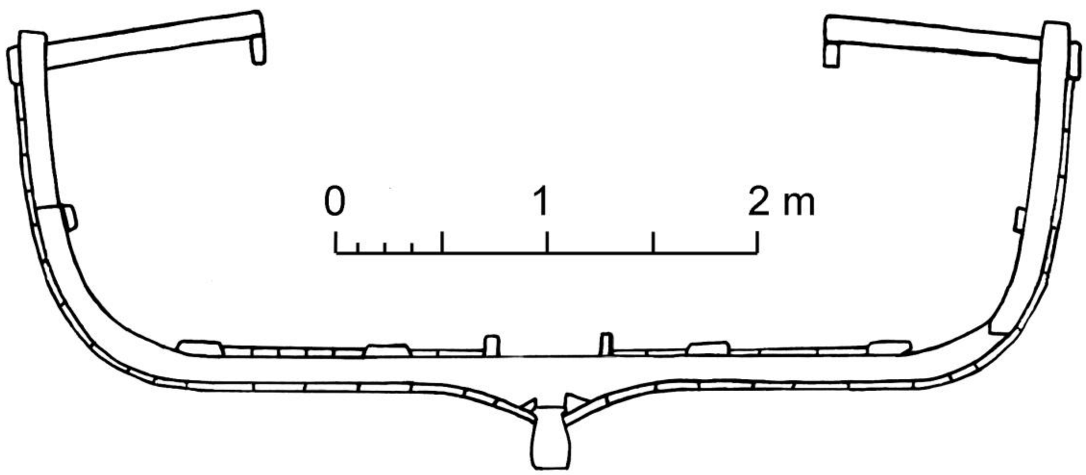

Figure 7.13: Reconstructed midship section of the Bozburun ship (After Harpster 2005a, 484, Fig. 5-24).

Examination of the ship's hull planking during the excavation and the lack of mortise-and-tenon joints led the excavators in the field to conclude that it was a skeleton-built ship.[805] However, during the cataloging of the hull timbers, wooden coaks were found in the edges of the planks, similar in size and shape to the ones later found on YK 14 and other Yenikapı shipwrecks; one plank had a preserved score mark indicating the location

[803] Harpster 2005a, 464, Fig. 5-24.
[804] Harpster 2005a, 126-31, 172-73.
[805] Hocker 1998b, 9-10.

of a coak, similar to those found at coak locations on YK 14.[806] A total of 119 joints fastened with oak coaks were found during the cataloging of the hull timbers, with only a reported 66 of them aligning with coaks on the opposite plank seam; the plank edges were badly worn and much damaged by shipworms in most areas, so the broken coak ends were very difficult to spot.[807] The coaks vary in spacing from 6.5 cm to 260 cm, with an average spacing of 59 cm.[808] Recorded coaks in the hull planking were spaced rather widely and in an irregular fashion. Harpster (2005a) proposes that these coaks were used to align the planks during construction and played no role in the structural strength of the hull.[809] Pomey et al. (2012) disagree with this interpretation, stating that coaks were added to the Bozburun ship's hull to provide additional longitudinal strength, an interpretation supported by the relative lack of major longitudinal timbers on the ninth- and tenth-century Yenikapı roundships built with coak-fastened hull planking.[810]

While the Yenikapı galleys have widely and sometimes irregularly-spaced coak joints, regularly-spaced coaks were the norm on many of the roundships from the eighth century onwards. The Bozburun ship appears to be a different, but related class of vessel

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[806] Harpster 2005b, 89-92.
[807] Harpster 2005a, 219-34. Harpster (2005b, 90) describes a technique used to locate coaks by submerging the timbers in water: "While submerging the fragment and delicately cleaning the plank's edge, the dowel's abraded end-grain absorbs more light than the surrounding wood, and any dowels present are revealed as dark circles along the edge of the fragment. As both the planking and the dowels of the Bozburun are oak, this discoloration was often the only means of finding dowels still in place." This description seems to indicate that the plank edges were badly scoured by sand on the seabed after the ship's sinking, and that the plank seams had separated. No such methods were required for locating coaks on the planks of the Yenikapı ships in most areas due to the excellent preservation of the timbers and the fact that plank seams had stayed together, although I did have some difficulty in locating a few coaks on one exposed and badly worn plank edge in the stern on PS 6-1.
[808] Harpster 2005a, 228.
[809] Harpster 2005b, 92.
[810] Pomey et al. 2012, 299.

to YK 14 and other tenth-century roundships from Yenikapı; the heavily-built YK 23 ship appears to be the closest parallel from the Yenikapı site, based on its oak construction, hull shape, and coak-fastened planking, although YK 23 was not built with in-line frames. The Bozburun ship's comparatively heavy scantling, as well as the presence of a galley hearth similar to that on the seventh-century Yassıada ship, suggests its likely use as a seagoing vessel for long-distance voyages, in contrast to the lightly-built Yenikapı roundships. The evidence for bolt holes in the Bozburun ship's keel and iron bolt concretions from the wreck site also suggest that longitudinal sister-keelson-like timbers could have been used in the hull for additional longitudinal strength, similar to those on YK 11 and 23, in addition to the wales and perhaps a full deck. The combination of oak and pine used in the Bozburun ship's construction as well as its heavier construction may indicate its origin in the Aegean or southern Anatolian coast.

In his reconstruction of the ship, Harpster proposes that, like the Serçe Limanı ship, the Bozburun ship was built using a set of molds to design six pre-erected midship and tail frames.[811] Proportions of surviving timbers suggest that a 'foot' of 34.5 cm was used in the construction of the hull.[812] The ship's heavy framing would have been more effective as 'active' frames than the light, irregular frames of YK 14. But the presence of large numbers of coaks in the Bozburun ship's hull, as well as the clearly central role they play in the construction sequence and hull strength of the Yenikapı ships, suggests that the role of coaks in the hull of the Bozburun ship should be re-examined. The large

[811] Harpster 2009, 302-10.
[812] Harpster 2009, 302.

numbers of ‘blind’ coak holes in the Bozburun ship’s hull suggests that coak joints were likely missed, perhaps due to poor preservation or scouring of the timbers by sand after the ship’s sinking. Based on the ship’s heavy framing, large keel, thick planking, and internal longitudinal timbers, it is possible that the coaks played only a minimal role in providing additional strength to the hull, although this now seems less likely in light of their use on the otherwise lightly-built hulls of the later Yenikapı roundships. The relatively large numbers of coaks in the Bozburun ship’s hull suggests that they played a significant role in the early stages of the ship’s assembly; based on comparison with the Yenikapı roundships ships, the Bozburun ship is likely a mixed-construction vessel, perhaps with some pre-erected ‘active’ frames.[813] The possibility that coak-fastened hull planks were replaced with repair pieces without edge fasteners should be reconsidered as well in light of the extensive repairs seen on some of the Yenikapı ships. The hull shape of the Bozburun ship closely resembles that of earlier roundships on the Yenikapı site as well as many other Roman and early Byzantine ships, but the ‘L’-shaped in-line frames scarfed for futtocks, show a link to the later Yenikapı roundships as well.

The Serçe Limanı Ship

Excavated between 1977 and 1979, the Serçe Limanı ship is the first Byzantine vessel demonstrated to have been built using a frame-first method. The Serçe Limanı ship sank off the coast of southwest Turkey some time after 1025, with a cargo of glass from Syria, including raw glass, factory waste, and complete vessels, as well as over one

[813] This interpretation is supported by Pomey et al. (2012, 299).

hundred wine amphoras, personal possessions of the crew, ship's equipment, and a large cargo of perishable material which was not recovered, perhaps soda ash used in glass manufacture.[814] The crew probably numbered eleven men, based on bundles of javelins and the abbreviated names inscribed on the wine amphoras, which appear to have been divided between the captain and crew.[815] The crew's weapons, some of the galley wares, fishing-net weights and other lead-containing objects (which contain lead from sources in the Rhodope Mountains), and some of the graffiti on the amphoras show a strong link to Bulgaria and the Sea of Marmara region. At least part of the crew were ethnic Bulgars, perhaps individuals who had been re-settled in the Sea of Marmara area after the conquest of the Bulgar Empire in 1018 by the Byzantine emperor Basil II.[816] However, other pieces of the ship's well-used galley wares were likely made near Beirut, suggesting a significant connection with the Fatimid caliphate. Many of the metal, glass, and glazed ceramic artifacts containing lead were traced by lead-isotope analyses to sources in north or central Iran, and the balance weights and weighing equipment on board would have been suitable for commercial transactions in both Byzantine- and Fatimid-controlled territories.[817] The ship sank with a cargo of glass and possibly soda ash from Syria and likely destined for Constantinople, a known center of glass manufacture.[818]

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[814] Bass et al. 2004, 251-52, 266-67; see also Bass et al. 2009; van Doorninck 2002b, 140, 143; Stos-Gale 2004, 466. For the export of raw glass and plant ash from Syria in the early medieval period, see Whitehouse 2003 and Henderson et al. 2009.
[815] van Doorninck 1989, 253-56; 1995, 183; 2002b, 140.
[816] van Doorninck 2002b, 139-43; 2012, 127-32.
[817] van Doorninck 2002b, 143; 2012, 131; see also Bass et al. 2004, 466; Stos-Gale 2004, 466; Waksman 2011.
[818] van Doorninck 2002a, 903; 2002b, 140-41; 2012, 127-31.

The units of measurements used in the construction of the ship are close to the Byzantine foot, indicating that the vessel was built by a Byzantine shipwright.[819] The use of Turkish pine (*P. brutia*) for nearly all of the timbers in the ship suggest that it was constructed along the Aegean or Mediterranean coast of Turkey, where this species is common today, rather than the Sea of Marmara area, where it is not.[820] Based on the large number of items on board originating in Bulgaria or the Sea of Marmara region, van Doorninck believes that the Serçe Limanı ship's crew originated from the Sea of Marmara region. However, based on the modern distribution of *P. brutia* and the origin of a number of items on board the ship, he suggests it was likely built elsewhere in the empire (van Doorninck suggests the region around Antioch). Regardless of the ship's origin, it was clearly used for regular trade with Fatimid Syria.[821]

About twenty percent of the Serçe Limanı ship's original hull survived, and is reconstructed with a length of 15.65 m, a beam of 5.1 m, a hold depth of 1.6 m, and a cargo capacity of approximately 35 tons burden (**Figure 7.14**).[822] The ship's rectangular keel was approximately 16 cm molded and 12 cm sided. Only the ends of the keel and the endposts were rabbeted; a larger keelson with an 18 cm molded and 20 cm sided dimensions was also bolted to the keel at regular intervals across the length of the

[819] van Doorninck 2012, 132.
[820] van Doorninck 2012, 132.
[821] van Doorninck 2012, 132.
[822] Bass et al. 2004, 166-67.

ship.[823] A single frame from the ship was made of elm, but the rest of the hull was built of Turkish pine (*Pinus brutia*); most frame and plank timbers appear to have been shaped almost entirely by sawing, with little additional adze dubbing.[824]

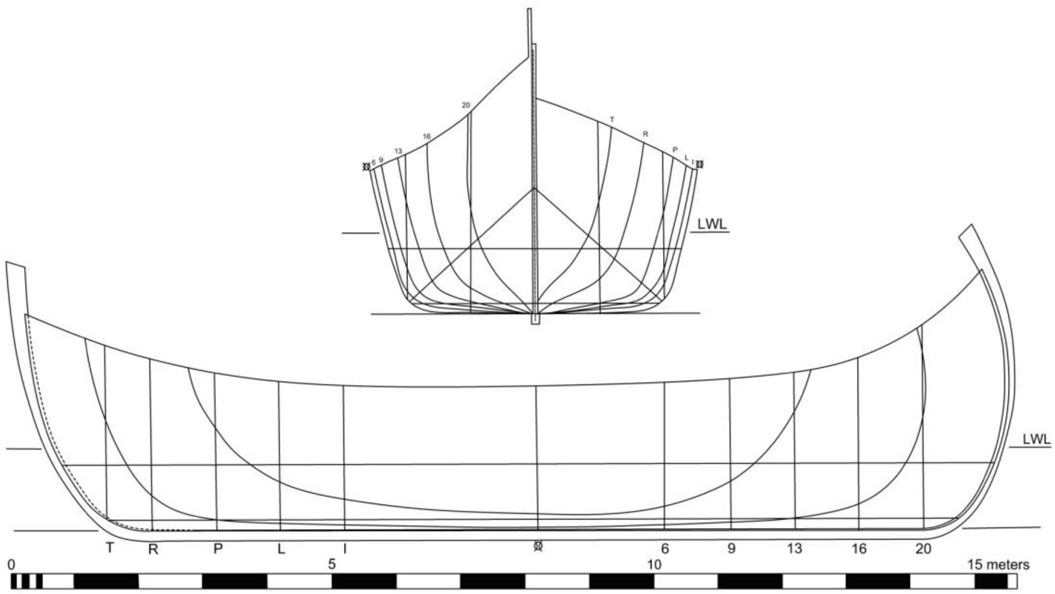

Figure 7.14: Reconstructed lines of the Serçe Limanı ship (After Bass et al. 2004, 166, Fig. 10-11).

No edge fasteners were found on the plank edges except for toenailed scarf tips and nails used to fasten the tips of the garboard strakes and hood ends; traces of caulking were found in a few locations along plank seams, as well as caulking irons among the tools on

[823] Bass et al. 2004, 85-8, 154, 113, 115-16, 164.
[824] Bass et al. 2004, 86-7, 153-54. In the final report on the hull, the keel timbers are identified as elm (presumably *Ulmus campestris*), but Liphschitz identified the timber as Turkish pine (*P. brutia*) (Liphschitz and Pulak 2007/2008, 75-6).

board.[825] Hull planks were on average 4 cm thick; planking scarfs included S-scarfs and three-planed scarfs (only a few of which were toenailed) as well as butt scarfs, and the keel and endposts were joined with flat scarfs which were nailed together.[826] The ship was flat-floored, with L-shaped floors and scarfed to futtocks and nailed together (**Figure 7.15**).[827] Frame cross sections were typically 16 cm molded and 12 cm in sided dimension, and were spaced approximately 33 cm apart; every floor timber was nailed to the keel.[828] Based on the location of a concreted group of anchors and remnants of deck planking on the wreck site, the ship appears to have been fully decked.[829] The frames and planking were fastened together primarily with iron nails, but some treenails were also used; the treenails, which seemed to consistently avoid nail positions, may have been repair fasteners.[830] Based on the repair planks in the hull, the possible repair treenails, and evidence of multiple applications of pitch on the outside of some timbers, Steffy suggests that the Serçe Limanı ship was an old vessel when it sank, perhaps having been used for up to ten or twenty years.[831] Although evidence for the ship's rig is fragmentary, gaps in the cargo and ballast which may correspond to mast step locations, study of the rigging blocks found on the shipwreck, and an analysis of the stability of the hull suggest that the ship had two masts rigged with lateen sails.[832]

[825] Bass et al. 2004, 107, 109-12, 312-13.
[826] Bass et al. 2004, 103, 154-55.
[827] Bass et al. 2004, 94-5, 157. These scarf ends were nailed together more securely than those seen on YK 14 and other Yenikapı ships.
[828] Bass et al. 2004, 94, 96, 98.
[829] Bass et al. 2004, 165, 230-31.
[830] Bass et al. 2004, 98, 107, 165.
[831] Bass et al. 2004, 165.
[832] Bass et al. 2004, 171-87.

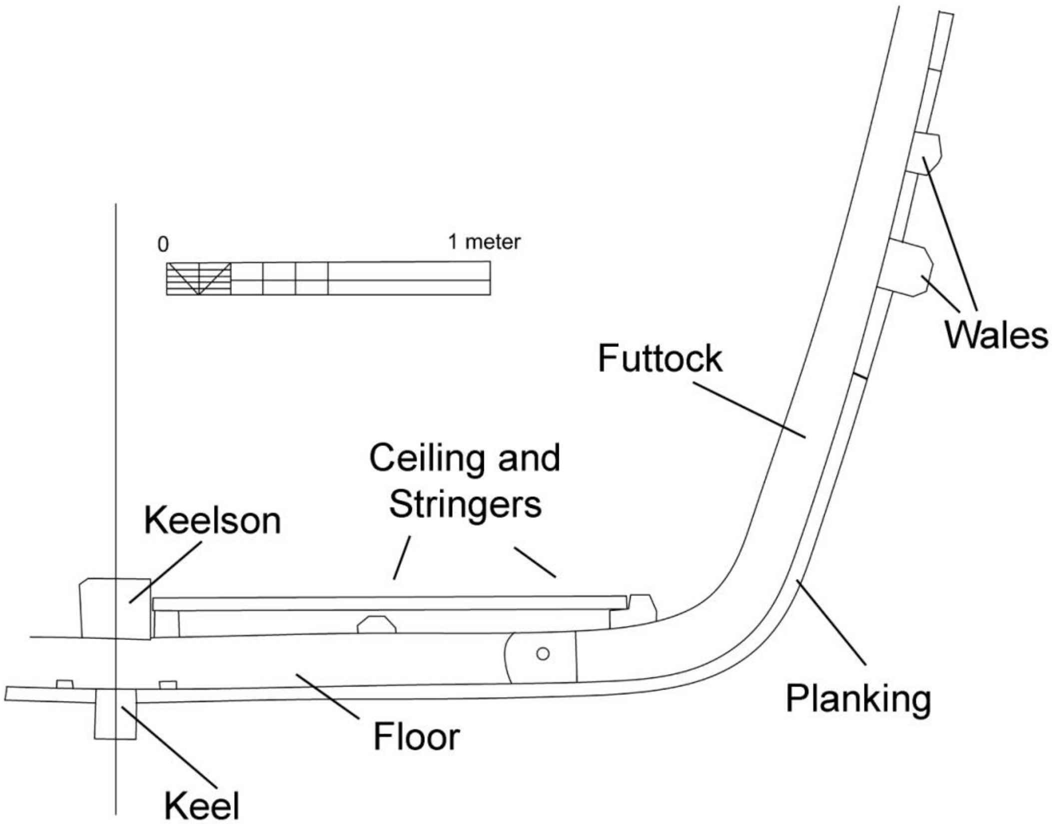

Figure 7.15: Steffy's midship frame reconstruction of the Serçe Limanı ship (After Bass et al. 2004, 197, Fig. 10-5).

Steffy reconstructed the skeleton-building method for the construction of the ship in the following way. The ship appears to have been built using standing frames erected on the keel timbers, including a group amidships and near the ends of the ship, and battens run between the frames. The proportions of the ship seem to have been based on proportions of a unit of approximately 32 cm (one 'Serçe Limanı foot' or 'SL'), which were further divided into a 16 cm unit called a 'quat' by Steffy.[833] Van Doorninck noted that the Serçe Limanı foot corresponded closely to one Byzantine foot (31.2 cm).[834]

The two midship frames are reconstructed as a pair of standing full frames whose shape was projected on the ground before assembly. Each midship frame consisted of an L-shaped floor timber fastened to two futtocks 2.56 m (8 SL ft.) wide and 1.92 m (6 SL ft.) high on either side of the keel, which was one SL foot wide at the center of the floor; The deadrise amidships was calculated as 1 'oct' (4 cm).[835] The two midship frames were then erected approximately 1 SL foot apart and supported with cross spawls. Six other floors were then added at set intervals with the necessary corresponding 'rising and narrowing' of their shapes. Based on experimental reconstructions with research models, two tail frames, one each at either end of the hull, must have also been necessary in order to plank the hull past the fourth strake due to stress on the planking. Steffy reconstructs the tail frames as a pair of heavy half-frames fastened to each other and positioned at the locations of maximum stress to the planking.[836] The general shape of the remaining frames could have been determined by battens fastened to the pre-erected frames.[837] Some of the frames did not have predetermined shapes and were clearly added later, as indicated by features such as nail-head impressions on the inner faces of hull planks under frame locations, nails that "nearly missed the frames—usually a sign of timbers

[833] Bass et al. 2004, 154; see also van Doorninck 2012, 132.
[834] Bass et al. 2004, 154; C. Pulak, personal communication.
[835] Bass et al. 2004, 155-56.
[836] Bass et al. 2004, 156-59.
[837] Bass et al. 2004, 160-61.

having been nailed after they were obscured by planking," and other floor timbers that were too crooked or angular to have had predetermined shapes.[838]

This relatively simple method for predetermining the shapes of key frames in the Serçe Limanı ship's hull would have been sufficient for constructing the hull with almost no edge fasteners in the planking, other than a few nailed scarf ends. The flat-floored, box-like shape of the ship's hull, in addition to being desirable from the perspective of cargo capacity, also simplified the process of pre-fabricating frames using simple geometric proportions, and the ship's full keelson, a heavier timber than the keel, gave the hull additional longitudinal strength necessary for a seagoing ship.[839] This method is similar to later hull construction methods documented on shipwrecks and in written documents from the late thirteenth century onward.[840]

The construction methods used in the later Yenikapı ships also bear a close resemblance to those used in the construction of the Serçe Limanı ship; YK 5 in particular has similar overall dimensions and a similar wide, flat-bottomed hull shape, similar L-shaped floor timbers scarfed to futtocks, and S- and diagonal-scarfs in the hull planking. The methods used in the Serçe Limanı ship could have developed as a vessel for long-distance trade adapted from ships similar to YK 5 used as coasters on the Sea of Marmara and the Aegean coasts.

[838] Bass et al. 2004, 159.
[839] Bass et al. 2004, 167.
[840] Bass et al. 2004, 158.

The design method used to build the Serçe Limanı ship must have been invented at least some years before the ship sank some time after 1025. Besides the shipwrecks mentioned on the Turkish coast, the tenth-century ‘Saracen’ Agay A and the Bataiguier shipwrecks, investigated off the Mediterranean coast of France near Cannes, display some similar characteristics; these ships were also built with flat floors, and without edge fasteners in the hull planking.[841] The Bataiguier ship has markings on the keel’s inner face amidships which suggest pre-planned design methods, probably for the positioning of ‘active’ (?) midship frames.[842] The similarities in hull shape and other features between these vessels and the Serçe Limanı ship have been noted by Rieth and Pomey, who propose a construction method “based on frames” for these ships.[843] Although this is a likely explanation for the hull’s characteristics, these wrecks have not been fully excavated or dismantled. It is therefore difficult to conclusively prove that methods other than frame-based or skeleton-first construction that could potentially produce similar results were not employed, such as the use of molds or temporary frames or cleats.

[841] Joncheray 2007a, 219-21; 2007b, 233-41.
[842] Joncheray 2007a, 221.
[843] Rieth 2008, 54-7; see also Pomey et al. 2012, 304.

5) The Tantura Shipwrecks

The largest group of Byzantine-era vessels found outside of Istanbul were discovered off the coast of Israel in Tantura Lagoon, near Tel Dor, about 30 km south of Haifa.[844] Regular surveys since 1979 by the Israeli Antiquities Authority, the Maritime Studies Program of the University of Haifa, and INA have uncovered the hull remains of an estimated 25 shipwrecks, ten of which have been excavated and recorded in-situ since the 1990s.[845] The shipwrecks range in date from the Late Roman and Middle Byzantine/Abbasid periods to the Late Ottoman period.[846] Of the shipwrecks studied at Tantura, only Tantura C and D, built with pegged mortise-and-tenon joints, and Dor D, built with unpegged mortise-and-tenon joints, have been identified as Late Roman or early Byzantine shipwrecks built using shell-first construction methods.[847] Five other shipwrecks—Tantura A, B, E, F, and Dor 2001/1—have been identified as 'frame-based' vessels.[848] The characteristics of these vessels are briefly described below, based on preliminary reports on their construction.

Tantura A

Tantura A is identified as a small coaster, originally about 12 m long and 4 m in beam, and dating to the late fifth or early sixth century C.E.[849] The keel had a rectangular cross section, 18 cm molded and 11 cm sided on average; only part of the single surviving

[844] Wachsmann and Raveh 1984; see also Kingsley and Raveh 1996; Wachsmann and Kahanov 1997.
[845] Kahanov 2011, 169; see also Kingsley and Raveh 1996, 55-75; Wachsmann and Kahanov 1997; Wachsmann et al. 1997.
[846] Kahanov 2011, 171.
[847] Pomey et al. 2012, 262-63; Wachsmann 2011, 88.
[848] Kahanov 2010, 82; 2011a, 150-51.
[849] Pomey et al. 2012, 259.

endpost was rabbeted.[850] The framing pattern was difficult to determine due to poor preservation, possible configurations include in-line, L-shaped frames or some arrangement of floors and paired half-frames.[851] The surviving frames were on average 9.5 cm molded and 9 cm sided, with an average room and space of 32.4 cm.[852] All of the frames were fastened to the keel and to the hull planking with iron nails; the garboards were not connected to the keel, nor were any edge fasteners found in the plank seams.[853] The ship's hull planking is 2.5 cm thick on average, and individual plank are joined with butt scarfs (with one exception of a diagonal scarf); caulking was found in the ship's plank seams, and a few of the planks are identifiable as repairs.[854] The charred inner face surface of some hull planks appears to be evidence of char-bending.[855] Based on the lack of edge fasteners in the hull's planking, plank seam caulking, frames nailed to the keel of the ship, and garboards that were not fastened to the ship's keel, Tantura A has been proposed both as an example of the "early stage of the transition" to skeleton building in the Mediterranean (Pomey et al. 2012) and as "a complete transition to a frame-based hull construction about half a millennium earlier than previously thought" (Wachsmann 2011).[856]

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[850] Kahanov et al. 2004, 113-15.
[851] See Kahanov et al. (2004 116, Fig. 8.5), for a plan of the shipwreck showing frame positions.
[852] Kahanov et al. 2004, 115-16.
[853] Kahanov et al. 2004, 116-18.
[854] Kahanov et al. 2004, 116-17.
[855] Wachsmann et al. 1997, 6.
[856] Pomey et al. 2012, 259-60; see also Kahanov et al. 2004, 113-18; Wachsmann 2011, 86.

Tantura B

Tantura B is dated to the early ninth century C.E. based on artifact finds and radiocarbon dating of hull timbers and other material from the ship. The ship is estimated to have been approximately 18-23 meters long and 5 meters in beam, and was built of Turkish pine (*Pinus brutia*).[857]

The keel timbers and endpost timbers are rectangular in section, with typical dimensions of approximately 9.5 cm molded and 10.4 cm sided; the keel is rockered, rabbets are found only on one endpost.[858] A 7.84 m-long, tapered keelson (with molded dimensions of 15.7-18.0 cm and sided dimensions of 12.2-20.2 cm) consisting of two parts also ran the length of the ship and was secured to the frames with iron nails.[859] A recess cut into the keelson served as a mast step.[860] Tantura B was a relatively flat-floored vessel; the cross-sectional dimensions of the frames are 9.6-9.7 cm on average.[861] The ship's framing pattern consists of floors alternating with paired half-frames. All frame timbers crossing the keel were nailed to it, although half-frames were not nailed to each other; iron nails were also used to fasten the frames to the hull planking.[862] No futtocks survived, although concretions of futtock fasteners are visible on the ends of floors: "the impression was not of strong connections" between floors and futtocks.[863] Plank seams were caulked, and no planking edge fasteners were found. Planks were approximately 3

[857] Kahanov et al. 2004, 19-22; see also Pomey et al. 2012, 271.
[858] Kahanov et al. 2004, 119.
[859] Kahanov et al. 2004, 119.
[860] Pomey et al. 2012, 271.
[861] Pomey et al. 2012, 271.
[862] Pomey et al. 2012, 271.
[863] Pomey et al. 2012, 271.

cm thick and were joined with butt or L-shaped scarfs; one strake in the hull may be a wale or bilge keel, 10 cm wide and 8.5 cm thick.[864] A stringer was fastened to the frames on either side of the keel, averaging 6.9 cm wide and 9.2 cm thick.[865]

H. Khalilieh suggests the Tantura B vessel was a galley, perhaps a type of ‘sea to river’ vessel which could be rowed. Tantura B seems to share several characteristics with a vessel called an *ʿushārī*, mentioned in the Cairo Geniza documents. The *ʿushārī* was a vessel that was sailed but also rowed; it was used both as a merchant vessel and a warship, both on the Nile and on the open sea.[866] This identification as a rowed vessel is plausible based on the ship’s hull characteristics and its close resemblance to the Yenikapı galleys: the ship has a full keelson with a mast step mortise, alternating floors and paired half-frames fastened to the keel. The proposed length-to-beam ratio of the ship is between 3.6:1 to 4.6:1. These dimensions would perhaps be suitable for a sailed ship that sometimes utilized auxiliary oars.

Tantura E

Tantura E, found on the western side of the lagoon, is preserved over an area of approximately 7.6 x 3.1 m, which includes 44 frame timbers, a keel and false keel, a transitional keel timber, part of an endpost, seven stringers and thirteen ceiling planks, a bulkhead support, and a stanchion.[867] The hull is dated between the seventh and ninth

[864] Kahanov et al. 2004, 122.
[865] Kahanov et al. 2004, 120.
[866] Khalilieh 2005, 314-19.
[867] Israeli and Kahanov 2012, 43.

centuries, based on an amphora found in its hull and on radiocarbon dating of samples from the ship's hull timbers.[868]

The keel of the ship is rabbeted and was shaped with a roughly rectangular cross section, 10 cm sided and 17 cm molded, and was fitted with a false keel on its outer face.[869] A 2.14 m-long central longitudinal timber was notched to fit over the floors on one end of the ship; the excavators believe it is not a true keelson, which would extend across the length of the ship, but rather a timber similar to the sternsons and stemsons seen on vessels such as YK 11 and 23.[870] The ship also had a transverse grooved timber positioned between two floors that may have served for the base of a removable bulkhead; a stanchion found nearby may have also been part of this arrangement.[871] The hull was framed with alternating floors and paired half-frames, with average molded dimensions of 12 cm and sided dimensions of 10 cm.[872] Most frames were fixed to the keel with iron nails, which were also used to fasten the frames and planking.[873] One ceiling plank recycled from another vessel contained a pegged mortise-and-tenon joint, one of the only examples from the Tantura site.[874]

[868] Israeli and Kahanov 2012, 46.
[869] Israeli and Kahanov 2012, 44.
[870] Pomey et al. 2012, 271.
[871] Israeli and Kahanov 2012, 45.
[872] Israeli and Kahanov 2012, 44.
[873] Israeli and Kahanov 2012, 44.
[874] Pomey et al. 2012, 271. A single tenon in one of Dor D's hull planking was pegged on one side, perhaps due to its position in a scarf end (Kahanov and Royal 2001, 262), while Tantura D was also built with pegged mortise-and-tenon joints (Wachsmann 2011, 88).

The plank seams of the ship were caulked, and no planking edge fasteners were found.[875] The hull planks were remarkably short and irregular, and joined end to end with butt joints; the excavators were able to identify at least a dozen repair pieces in the hull planking.[876] Based on these characteristics of the hull, the excavators identify Tantura E as a frame-based vessel.[877]

Tantura F

Tantura F's hull remains were discovered over an area of 12 x 5 m northwest of the lagoon's navigable channel.[878] The original hull is estimated to have been about 16 meters long, with a beam of 5.5 meters, and may have been a local coaster or fishing boat.[879] The ship is dated based on radiocarbon dating of hull timbers and the pottery found in the shipwreck, which date between the mid-seventh and late eighth centuries C.E.; petrographic analysis of the ceramics from the ship indicate an origin for some of the ceramic vessels in the Nile Delta and southern Turkey or the Troodos Mountains of Cyprus, perhaps an indication of the vessel's sphere of activity.[880] The ship's keel, some frames, stringers, and mast step assemblage were constructed of Turkish pine (*P. brutia*), while the remaining frames and central longitudinal timbers were made from a tamarisk (*Tamarix* X5*)* species. The *Tamarix* species could be *Tamarix smyrnensis,* which grows in Turkey in the areas of Izmir, Edirne, Antalya, and Cyprus, or a local subspecies from

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[875] Israeli and Kahanov 2012, 44-5.
[876] Israeli and Kahanov 2012.
[877] Israeli and Kahanov 2012, 46; see also Pomey et al, 2012, 271.
[878] Barkai 2009, 25.
[879] Barkai and Kahanov 2007, 28; see also Barkai 2010, 98.
[880] Barkai et al. 2010, 95-6, 98-100.

the Israeli coast.[881] Turkish pine (*P. brutia*) grows in the eastern Aegean islands, Turkey, Crete, Cyprus, Syria, and Lebanon, but is only a recent import to Israel.[882]

Tantura F's hull is well preserved. The keel timbers, which survived for a length of 12 meters, was approximately 9.5-10 cm sided and 16-18 cm molded; only the endposts were rabbeted, and no fasteners connecting the garboards to the keel were found.[883] The hull was fastened entirely with iron nails.[884] Thirty one frames and 36 frame stations were preserved, out of a reconstructed total of 44 frame stations; the framing pattern consisted of floors, pairs of alternating half-frames, and futtocks, except under the mast step, where a series of floors were positioned, and in the bow, where floor timbers with alternating long and short arms were located.[885] Frames were typically about 11 x 8 cm in cross section, with an average room and space of 28 cm.[886] All but eight of the floor timbers were fastened to the keel. Some, but not all, of the half-frames were connected to each other with hook or diagonal scarfs, and were nailed to the keel but not to each other.[887] Parts of 15 minimally-worked futtocks were found nailed to floors from the sides, "randomly forward or aft" of the floor timbers; Barkai notes that the floor/futtock connection is "weak" and probably could not have stood on their own before planking was installed.[888]

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[881] Barkai 2010, 98.
[882] Barkai 2010, 98.
[883] Barkai 2010, 98; see also Barkai and Kahanov 2007, 22.
[884] Barkai 2010, 98.
[885] Barkai and Kahanov 2007, 23, 25, Fig, 8; see also Barkai 2010, 98.
[886] Barkai and Kahanov 2007, 23.
[887] Barkai 2009, 26.
[888] Barkai 2009, 26

Planks were on average 2.5 cm thick, and 21 of 22 plank scarfs were butt scarfs at frame stations (the twenty-second is a diagonal scarf); no edge fasteners were found in the plank seams, and the planking seams were caulked.[889] Internal timbers included a stemsom and sternsom at the bow and stern; the bow timber is 2 meters long, 14 cm sided, and 12 cm molded, while the stern timber is 1.42 m long, 14 cm sided, and 15.5 cm molded.[890] Six half-log stringers, three on either side of the keel, were nailed to the frames; these timbers are 15 cm wide and 6 cm thick.[891] The mast step was installed between two stringers: one on either side of the keel, and also supported by two lateral mast step sisters; the mast step has two mortises, one for the mast heel and the other likely for a stanchion to support the mast partner beam.[892] As with Tantura A, B, E, and Dor 2001/1, Tantura F is proposed as a frame-first construction based on the lack of edge fasteners and presence of caulking in the plank seams, the lack of edge fastenings between the garboards and the keel, the presence of strong longitudinal timbers in the hull, the type and location of planking scarfs, and the large number of frame timbers nailed to the keel.[893]

Dor 2001/1

Dor 2001/1 is dated to the first quarter of the sixth century C.E. based on radiocarbon dates and 'wiggle-matching' of dendrochronological samples of the ship's hull

[889] Barkai 2009, 27; 2010, 99; see also Barkai and Kahanov 2007, 24.
[890] Barkai 2010, 99.
[891] Barkai 2010, 99.
[892] Barkai 2010, 99.
[893] Barkai and Kahanov 2007, 28-9.

timbers.[894] The ship sank while carrying a cargo of 96 locally quarried *kurkar* sandstone blocks.[895] The remains of the ship covered an area of approximately 11.5 x 4.5 m; the vessel has been reconstructed with a length of 16.9 m from stem to sternpost, with a beam of 5.4 m, a depth of 2.5 m, and an estimated cargo capacity of 35-50 tons.[896]

The ship's keel, shaped from a log of European cypress (*Cupressus sempervirens*), survived to a length of almost eight meters and consists of two timbers, which are 14.5 cm molded and 11 cm sided on average. The keel timbers have no keel rabbet or chamfer (except at the endposts), and planking was butted against the keel without being fastened to it except at their ends to the endposts.[897] A false keel of oak (*Quercus coccifera*) was fastened to the outer face of the timber with iron nails.[898] Hull planks were fairly narrow, 10-17 cm wide and 2.5-3.0 cm thick.[899] The frames and planking were fastened with iron nails, and nearly all (41 of 44) of the frames were fastened to the keel.[900] The hull is flat-floored and built with a hard chine; the framing pattern consists of alternating floors and paired half-frames, approximately 10 x 10 cm in section, and with an average room and space of 24 cm.[901]

[894] Mor 2012, 42-3.
[895] Mor 2012, 43.
[896] Mor 2012, 43.
[897] Kahanov and Mor 2009, 18; see also Pomey et al. 2012, 261.
[898] Kahanov and Mor 2009, 18.
[899] Kahanov and Mor 2009, 20.
[900] Mor and Kahanov 2006, 275.
[901] Mor and Kahanov 2006, 276; see also Kahanov and Mor 2009, 18.

Full floors were inserted in the hull in the mast step area, which was identified by the presence of a mast step sister.[902] The half-frames were made from compass timber with a sharp elbow bend, "comparable to knees of inland boats built 'bottom-based,' and a few full frames were used at one end of the hull."[903] Part of the framing pattern of the hull was obscured by ceiling planking on the southeastern end on the ship, although at least three frames in this area are half frames.[904] The frames were made from seven wood species (*Fagus orientalis, Pinus brutia, Quercus cerris, Quercus coccifera, Ulmus campestris, Ziziphus spina-christi*, and *Tamarix* (X 5)). Only the last two grow locally near the shipwreck site, while the others grow on the coast of Turkey.[905] Plank seams were caulked and adjoined with butt joints, and no edge fasteners were found.[906] Longitudinal reinforcement timbers include a 2.55 m-long 'central longitudinal timber,' similar to a keelson, in addition to the keel and the bilge wales or chine strakes, which are about 10 cm wide and 6 cm thick (**Figure 7.16**).[907]

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[902] Mor and Kahanov 2006, 276, 281.
[903] Pomey et al. 2012, 261; see also Kahanov and Mor 2009, 18.
[904] Mor 2010, 88.
[905] Kahanov and Mor 2006, 20.
[906] Kahanov and Mor 2006, 20-2.
[907] Mor 2010, 89; see also Mor and Kahanov 2006, 276, Fig. 3, 278, Fig. 7, 279-80.

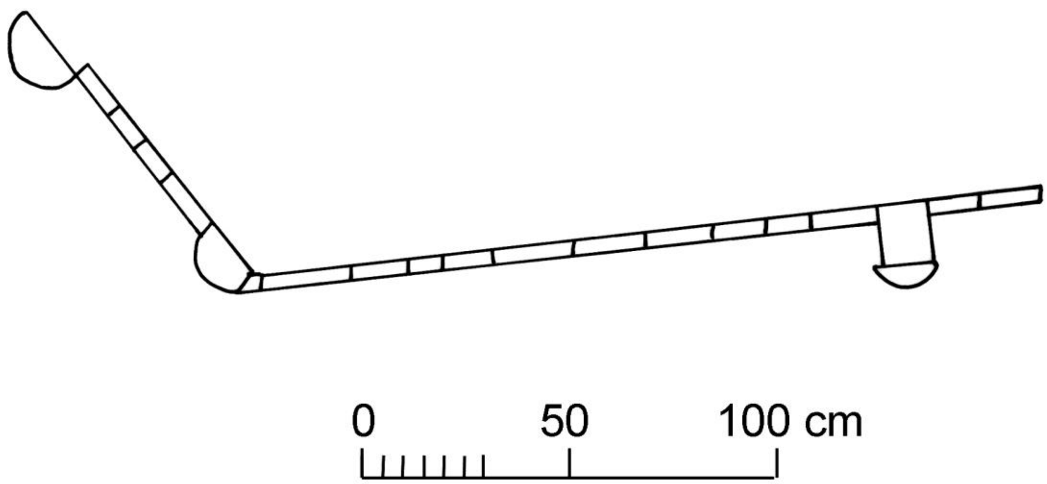

Figure 7.16: Cross section of the Dor 2001/1 vessel amidships (After Pomey et al. 2012, 261, Fig. 39).

A two-meter section of the central part of the hull was removed in 2005 in order to ascertain the construction methods and sequence used in the hull, specifically whether Dor 2001/1 was built using frame-based methods. According to Mor, the removal of the 2-meter section of the hull of the central section of the ship "proved beyond doubt that" the ship was "built frame-first."[908] The removed section included sections of the keel, false keel, central longitudinal timber, stringers, planks up to the second wale, and ceiling planks.[909] This interpretation of the hull was based on a number of characteristics:

[908] Mor 2012, 43.
[909] Kahanov and Mor 2009, 22.

1) Forty-one of the 44 frames were nailed to the keel, and the three frames not nailed to the keel were in a localized area which may have been repaired.

2) The garboards were not fastened to the keel.

3) Planks were nailed to the frames from the outside of the hull.

4) No plank edge fasteners were found.

5) Plank butt-joints were located at frame stations.

6) Caulking was found at all plank seams. [910]

Based on these characteristics, the construction sequence is proposed as beginning with the laying of the keel and endposts, after which some of the frames were installed to determine the shape of the bottom of the hull, although the exact order in which they were placed is not clear. Pre-erected frames would have consisted of full frames at either end of the hull; they may have required temporary supports or scaffolding, although "The scaffolding left no marks on the frames."[911] The chine strake may have been fastened to the hull at an early stage of construction to define the bilge shape, after which half-frames may have been inserted, to which the wales were attached. After these timbers were in place, the futtocks may have been inserted in the hull; one futtock was nailed to a floor timber and a second futtock, after which planking and the internal timbers were added to the hull.

[910] Mor 2010, 89.
[911] Mor 2010, 89.

Comparison of the Tantura Ships and Other Mediterranean Shipwrecks

Based on these vessels, there are two main groups of ships from the Tantura site. The first, represented by Dor D and Tantura C and D, are poorly preserved Late Roman or early Byzantine period vessels constructed using the similar methods to those seen in the fourth- and seventh-century Yassıada ships and several of the Yenikapı ships from the sixth and seventh centuries.[912] The methods used to build such ships are well-understood from the study of other, better preserved late antique shipwrecks. The second and more distinctive group, which includes Dor 2001/1 and Tantura A, B, E, and F, were built without edge fastened hull planking and with a variety of characteristics commonly ascribed to 'frame-first' construction.

They have some similarities with Byzantine wrecks from further west dated to between the sixth and ninth centuries. The Tantura ships' hulls are fastened exclusively with iron nails, and a framing pattern of alternating floors and paired half frames was certainly employed on four of the ships; a similar pattern may have been employed on the fifth (Tantura A). Most or all of the frames crossing the keel were nailed to the keel on each of these ships. Either central longitudinal timbers (stemsons and sternsons) or full keelsons were used for longitudinal stiffening on the ends of the hulls, in addition to stringers inside the hull, which were quite robust on several of the ships. The dimensions of the hull timbers are generally similar to those on YK 14 and many of the other Yenikapı ships: keel timbers are around 9.5-11 cm sided and 10.5-18 cm molded, frame

[912] Kahanov and Royal 2001; see also Wachsmann 2011, 88.

timbers have typical molded and sided dimensions of around 8-12 cm, and planking is 2.5-3.0 cm thick on average. As with the Yenikapı, Serçe Limanı, and Bozburun ships, the plank seams of these vessels were caulked. The Serçe Limanı ship and some of the Yenikapı ships, particularly after the ninth century, have flat floors and hard chines similar to most of the Tantura ships. The bilge wales of Dor 2001/1 resemble those of YK 17, which was also built without edge fasteners. Some of the same timber types were used as well, although the Tantura ships were built primarily with pine while many of the Yenikapı were built with oak. This is most likely due to local availability of timber or the sources of imported timber. The planking of the Tantura ships is in many cases more regular than that of the Yenikapı ships, a characteristic more common to skeleton-built hulls. If the planking is ignored, the Tantura ships are in fact quite similar to those from Yenikapı; the main differences are the use of flat floors with the framing pattern of alternating floors and paired half-frames, and the relatively heavy longitudinal reinforcement of the hulls, which is not seen in the ninth- and tenth-century Yenikapı roundships but is present in earlier vessels from Yenikapı.

The most significant differences in construction features of the five ships from Tantura occur in the hull planking. The plank seams lack edge fasteners, and the planks are almost always butt joints scarfed together under frames, a clear contrast from the (usually) edge-fastened S- or diagonal scarfs on earlier Roman shipwrecks and many of the Byzantine shipwrecks from the coast of Turkey. The garboard strakes are not fastened to the keel, a departure from a common feature of the Yenikapı ships with an origin in shell-first construction.[913] The frame shapes on these ships are simpler than those of ‘wine-glass’-shaped hulls, and could be pre-designed through simple geometric methods. For these reasons, these ships have been proposed as the earliest known examples of ‘framing first’ construction in the Mediterranean, dating to the early sixth century. This construction method is defined as using the shapes of a few pre-designed frames to help determine the shape of the hull during construction, as with the design methods reconstructed by Steffy for the Serçe Limanı ship. This method contrasts with ‘true’ skeleton-first shipbuilding, in which geometric rules are used to determine the shape of nearly all of the frames and for which there is currently no evidence before the late twelfth century.[914] Influence of the ‘Roman-Celtic’ shipbuilding tradition in northern Europe, which likely utilized control frames of a simple sort in the construction of some vessels as early as the second century C.E., has also been proposed.[915]

Another issue concerns definitions: for example, how many ‘active’ frames are required at minimum for a ‘framing-first’ hull? Many scholars have commented on the fact that many shipbuilding methods mix construction techniques, and as a result they focus on the builder’s conception of the hull design, as far as it can be ascertained, to classify as

[913] The lack of keel/garboard fasteners (aside from toenailed scarf tips) as well as the lack of planking edge fasteners in the Serçe Limanı ship’s hull led Steffy to state that “There was never any doubt that frames came before planks,” although he was unable to ascertain the specific construction methods used before the discovery of the units of measurement and proportions used in designing the hull (Bass et al. 2004, 157).
[914] Kahanov 2011b, 176-77; see also Bonino 1978, 13; Palou et al. 1998; Nayling and McGrail 2004, 210.
[915] McGrail 2008, 626-27.

vessel's construction method.[916] The current terminology for describing vessel design and construction will inevitably be imprecise for some shipwrecks, particularly for those built in a transitional period in which older and newer construction and design methods may have been combined. Kahanov asks whether four characteristics, including the nailing of frames to the keel, plank butt scarfs at frame stations, absence of planking edge joints, and caulking in all seams, are enough to establish that a ship is frame-based.[917] Mor adds two additional characteristics: the absence of keel/garboard plank fastenings and planks nailed to the frames from the outside of the hull.[918] However, of these characteristics, seam caulking and the fastening of most or all frame timbers to the keel are both features found on the mixed construction (but essentially shell-first) hulls from Yenikapı such as YK 14. It is conceivable that other 'shell-first' solutions were applied to the construction of these ships that closely resemble framing-first construction features as well.

Although the Serçe Limanı ship was built using fully developed methods that may have been invented long before the ship's construction around 1000, 'bottom-based' methods of vessel construction could offer a plausible alternative explanation for at least some of the features in these hulls described as characteristics of 'framing-first' methods. The resemblances of the Tantura ships' to river vessels have already been noted, as well as

[916] Hocker 2004a, 6-7; see also Basch 1972, 15-9; McGrail 1997; Nayling and McGrail 2004, 197-211; Pomey 2004, 25-9.
[917] Kahanov 2010, 79.
[918] Mor 2010, 89.

the numerous references to 'river to sea' vessels in the Cairo Geniza documents.[919] In the seventeenth century, flat-bottomed hulls with a hard chine were constructed in the Dutch bottom-based construction tradition using temporary cleats or clamps.[920] Similar construction methods are documented in 'Romano-Celtic' tradition, especially in the first-century C.E. Bevaix boat, as well as in traditional vessel types documented in modern times.[921] Another potentially relevant example is the fourth-century Mainz boats; Bockius proposes the use of temporary molds to explain plugged holes in their hull planking. Hocker suggests the use of cleats as a more likely source for these plugged holes based on the distribution of the fasteners in the hull.[922] Many of these bottom-based or mixed-construction methods include the use of temporary molds or the inclusion of frames in the early stages of construction, but conceptually they are closer to shell-first construction in that the basic element of the construction in the shaping of the hull is the longitudinal control provided by bottom planking rather than transverse sections provided by framing.[923]

The use of these methods in hull construction is usually only evident from rows of plugged fastener holes in the hull planking with no other obvious function. Fastener holes plugged with wooden pegs, called *spijkerpennen*, from the use of temporary cleats

[919] Pomey et al. 2012, 302-4; see also Rieth 2008, 66-8.
[920] Lemée 2002, 113, 123-28.
[921] Hocker 2004b, 68-9, 71; see also Greenhill 1971, 179-81; Basch 1972, 17-9; Arnold 1975.
[922] Bockius 2009; see also Hocker 2004b, 72.
[923] Hocker 2004b, 65, 85. Pomey et al. (2012, 304-5) allow that some Romano-Celtic influence could have influenced frame-based construction, but see the role of the keel as central in the development of framing-first construction; see also Kahanov 2010, 82. The independent invention of similar techniques should also be considered, perhaps based on older precedents from inland or regional construction traditions in the Mediterranean region, in particular the 'Nilotic' tradition proposed by Rieth (2008; see also Pomey et al. 2012, 308).

are a standard feature of Dutch bottom-based hull construction, and the plugged holes in the planking of the Bevaix boat and possibly other Romano-Celtic shipwrecks are probably from a similar technique as well.[924] Such evidence is difficult to analyze in many cases, since fastener holes in a ship's hull can be from any number of sources, and the presence of fastener holes for one or two temporary props or cleats does not establish or disprove the use of a particular method of construction. In general, however, a lack of evidence for significant use of temporary frames or cleats, in the form of rows of plugged fastener holes in the planking, should be an additional criterion for identifying a skeleton- or framing-first construction. Steffy's reconstruction of the Serçe Limanı ship also includes evidence for proportions used in the hull and trial-and-error-based research with wooden scale models of the timbers to find plausible methods for hull construction, a process also begun with the Tantura A ship.[925] Steffy was able in many cases to determine that frames were erected after the hull planking was in place; for example, nail head impressions were found around nail holes under floor timbers, indicating that the nails were driven and removed before the insertion of the frames, which were fastened using the same nail holes. In many cases, full excavation, dismantling, and detailed examination of a ship's hull will likely be required to establish the construction method and sequence.

Rieth argues that frame-based construction could have evolved from bottom-based construction, perhaps when bottom-based vessels were adapted for seagoing ships; he

[924] Arnold 1975, 125-26; see also Marsden 1994, 39-40, Fig. 26; Lemée 2002, 220-24.
[925] Kahanov 2011a, 139-43.

cites the flat bottoms, hard chines, and angular sides of Dor 2001/1 and other Tantura ships as well as the Serçe Limanı ship as possible evidence of this ancestry.[926] Rieth rightly points out that bottom-based or flat-floored hulls lend themselves to geometric methods of fabricating frame shapes. However, the later coak-built Yenikapı roundships seem to suggest that similar, 'geometric' frames and hull shapes can also be arrived at through a variety of other design and construction methods, and are not necessarily an indicator of true frame-based construction.[927] For this reason, hull shape or hull geometry alone should not be considered a definitive indicator of a particular design method, although the proposed evolution from bottom-based river vessels to framing-based construction is plausible and warrants further investigation.

The role of repairs in hulls should also be taken into account. Hull repairs were present in most of the Yenikapı ships studied by INA, and several of the vessels showed signs of significant overhauls, which could potentially confuse the interpretation of their construction. If much of the original planking was replaced, it is sometimes difficult to ascertain whether the original hull planking was built with edge fasteners. YK 11 was particularly instructive in this respect. The original hull planking was fastened with unpegged mortise-and-tenon joints, but over the course of the ship's use-life, much of the edge-fastened hull planking was replaced. Although YK 11 proved to be built shell-first to the waterline, this could not be proven until the hull was fully dismantled and

[926] Rieth 2008, 64-7.
[927] Kahanov 2011a, 150-51; see also Pomey et al. 2012, 301-2.

cataloged.[928] It seems likely that Tantura E's patchwork of small, irregularly-shaped planks could be due to extensive repairs of a shell-built or mixed-construction hull rather than 'framing-first' construction.[929]

Although the Tantura and Yenikapı shipwreck assemblages can be interpreted differently, these discoveries show not only the complexity of the development of Mediterranean ship construction, but also the possibility of outlining distinct regional shipbuilding traditions. Eric Rieth and Lucien Basch present the hypothesis that the construction methods seen on the Tantura ships have an Egyptian root, perhaps in Alexandria, where the indigenous construction methods of Nile watercraft could have been mixed with the mainstream Greco-Roman shipbuilding tradition.[930] Flat floors with sharp chines are suggested as an indicator of this 'Nilotic' tradition.[931] Basch notes that references to professional caulkers (*kalaphates*) appear in papyri in the 560s, indicating that caulked vessels were common on the Nile by this period.[932] Some features in the Tantura ships that differ from other Mediterranean vessels may come from an older Egyptian construction tradition dating to the first millennium B.C.E. The planks of the Mataria boat, built of local Sycamore fig (*Ficus sycamoris*), and dated to the fifth century B.C.E., were scarfed with butt or half-lap scarfs.[933] The hull planking itself, however, was fastened with mortise-and-tenon joints, indicating clear foreign influences

[928] R. Ingram, personal communication.
[929] Israeli and Kahanov 2012, 44-5.
[930] Rieth 2008, 67; see also Basch 2008, 76-80; Kahanov 2011a, 150-51.
[931] Rieth 2008, 57-8; see also Kahanov 2011a, 150-51.
[932] Basch 2008, 78-9; see also Pryor and Jeffreys 2006, 150.
[933] Ward 2000, 129-31.

(probably Phoenician or Greek) in Egyptian shipbuilding of the period.[934] The use of caulking in plank seams may also have roots in Egyptian vessel construction; Herodotus mentions papyrus fibers as caulking—although this passage has been interpreted differently.[935] Caulking was recently found in a plank seam of a Late Period or Hellenistic Period ship (sixth to second century B.C.E.) at Heracleion-Thonis in the Bay of Aboukir, although it is unclear whether it is an original feature of the ship or a later repair.[936] Although this evidence is circumstantial, and adaptations to the social and economic conditions of the early Byzantine period must have determined many of the Tantura ships' features, the sources of the differences in construction between the Tantura ships and other Mediterranean vessels may become clearer with the discovery of older Egyptian shipwrecks.

The basic explanation for the changes seen in shipbuilding between c. 500-1000 C.E. first formulated decades ago still appear to be correct: the larger ships of the Hellenistic and early Imperial periods were no longer common, and were replaced by smaller, more cheaply-built ships which gradually dispensed with edge-fastened hull planking and developed frame-first construction. This change may have been accompanied by the re-assertion of old regional ship construction styles as well as the development of new ones. Such developments could account for the significant differences between the shipwreck assemblages from Yenikapı and Tantura. The extent of this process and the identification

[934] Ward 2000, 131-35.
[935] *Hdt.* II.96.1-2. Ward (2000, 124) suggests that Herodotus may have confused caulking with lashings of papyrus in a laced-construction hull.
[936] Fabre 2012, 18-9, Fig. 1.7.

of specific regional styles of construction should be done cautiously, however. Differences in hull construction may be due to local resources and environmental conditions or other factors, and should not necessarily be interpreted as a regional tradition. Regional maritime networks were never closed systems, and the most useful construction methods or hull designs may have spread quickly from their point of origin.

In spite of these caveats, it appears that the Sea of Marmara region and Egypt and the Levantine coast developed divergent, regional shipbuilding traditions by the Byzantine period, perhaps at least as early as the sixth century. The Yenikapı ships seem to retain more features of Greco-Roman shipbuilding techniques for a longer period, especially in the reliance on edge fasteners (in the vast majority of the ships) and in hull shape, while other features from shipwrecks on both sites (framing patterns, scantling, etc.) attest to their common roots. While shipbuilders in both the Levant and the Sea of Marmara/Aegean region seem to have responded to a need to build ships more cheaply and use local materials if possible, they met this challenge in different ways. Shipbuilders in Egypt and the Levant may have simply abandoned the use of edge fasteners in favor of other methods—if this had not in fact occurred well before the Late Roman period—while the shipwrights who built the Yenikapı roundships attempted to make edge-fastened hull construction as simple and efficient in materials as possible. By the tenth century, local coasters in the Sea of Marmara were built with a minimum of iron fasteners and large timbers, and the shipwrights of the region had developed a construction method that utilized the advantages of edge fasteners in the construction process without excessive labor. This construction style seems to have been sufficient for the large number of vessels used locally around Constantinople and the Sea of Marmara, and had at least some influence on the construction of larger seagoing ships as well.

CHAPTER VIII

CONCLUSION: YK 14 AND THE MARITIME TRADE OF CONSTANTINOPLE

Constantinople in the ninth and tenth centuries relied upon thousands of ships and small craft to function. Although significant shipments of nonperishable foodstuffs also arrived from more distant sources, most vessels transported basic necessities to the capital from the city's hinterland and adjacent provinces.[937] Aristocratic and ecclesiastical estates as well as port towns along the shores of the Sea of Marmara relied on merchants and their ships for the transport of their surplus grain and other agricultural products as well as that from the interior to the city; these voyages would have required several days or less to reach the markets of Constantinople.[938] Livestock was driven from neighboring regions and the interior of Asia Minor to ports on the the Sea of Marmara such as Nicomedia (modern Izmit) and Pylae (modern Yalova) to be transported to the city by ship as well.[939] The Bosporus provided abundant fish, caught both with nets and weirs near the shoreline and from local fishing vessels; the catch was brought daily to the city's harbors, either to be consumed fresh or salted and stored.[940]

Ships such as YK 14 would have been well-suited for this type of regional transport and trade. YK 14 was a medium-sized, shallow-draft coaster, approximately 14.7 meters

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[937] Harvey 1989, 146-47, 175, 204; see also Hendy 1985, 558; Koder 1995, 54; 2002, 115, 118-20; Mango 2000, 193, 199, 204-5; Dagron 2002, 446-49, 456-59; Günsenin 2009, 151-52.
[938] Dagron 2002, 450-52; see also Magdalino 1995, 39-46.
[939] Hendy 1985, 55, 558.
[940] Koder 2002, 112-13; see also Harvey 1989, 169-70, 204; Maniatis 2000, 21-2, 29-30; Dagron 2002, 447.

long, 3.5meters in beam, and with a hold depth of about 1.6 meters and a cargo capacity of approximately 12 tons. It is unlikely that the ship was fully decked. Its flat-floored construction and relatively small keel seem to indicate that YK 14, like many other ships of the period, was designed for sailing in shallow water and for beaching in areas with minimal harbor facilities. However, YK 14's hull is significantly narrower than some similarly-sized tenth-century roundships. This hull shape may indicate a specialized function; perhaps the ship was rowed with auxiliary oars as well as sailed. Based on evidence for the location of the mast step and archaeological and iconographic evidence for ship rigs of the period, YK 14 was sailed with a single lateen sail. The lateen sail is well-suited to fair-weather sailing and predictable wind conditions like those found the Mediterranean region (including the Sea of Marmara) throughout much of the year. YK 14's design is well-suited for the *cabotage* trade common throughout Mediterranean history; such merchant coasters typically sailed in sight of land, and crews frequently ate and slept on shore.[941] The long sailing season in the Mediterranean allowed such small vessels with minimal provisions and other amenities (such as crews' quarters) to play a major role in commerce and provide the bulk of provisions supplies needed by cities, including those as large as Constantinople.[942]

[941] The use of small vessels for short coastal voyages and *cabotage* trading has been a common feature of Mediterranean seafaring throughout history. Braudel (1995.1:104-9) notes that this type of commerce was common in the Renaissance period, while Pryor (2000, 48, 54-7: 2008, 483-86), Makris (2002, 94-5), and McCormick (2005, 422-23) indicate that this was typical in the early medieval period as well.
[942] Even in the late seventeenth and early eighteenth century, a large proportion of the Ottoman grain fleet consisted of small coasters 12-16 m in length (Murphey 1988, 223-24, Table 1).

Thanks to its quick burial in the sediments of the Theodosian Harbor, YK 14 is one of the best preserved shipwrecks of the 36 recovered from the Yenikapı site during the Marmaray Project excavations, and the vessel's features and sequence of construction can be determined with a high degree of accuracy. The ship was probably built by a single master shipwright with one or a few assistants, occasionally supplemented by specialists such as sawyers and caulkers. The ship's hull was built from relatively young trees; several species were used, but the vast majority of timbers were of Turkey oak, (*Quercus cerris*). This choice of timber probably represents what was locally available timber for shipbuilding, and is typical of the later roundships from Yenikapı. Evidence for the tools used in the shaping of the hull survives in the form of tool marks on the timbers themselves. The initial construction of the hull would have required the extensive use of two-man pit or rip saws to shape the hull planks. Curved compass timbers were also partly shaped by sawing, although smaller frame saws were likely used for this work. Saw marks survive on many of the planks and frames, but much of the final shaping of hull timbers was done using an adze. The keel timbers appear to have been shaped almost exclusively with adzes, as were the frames and much of the inner faces of the hull planking, which were dubbed to a relatively uniform thickness. Chisels and a small saw were used for keel scarf ends, mortises, grooves in futtocks for bulkhead partitions, and through-beam apertures in the hull planking.

After the keel and endpost timbers were rabbeted and fastened together, the garboard strakes were fastened to the keel using wooden coaks and iron nails driven into predrilled pilot holes. Wooden coaks were used exclusively to edge-fasten the hull planking from the second strake to the twelfth strake on the starboard side, below the first wale, which survived on the starboard side of the shipwreck. This process required the drilling of aligned holes (often marked with score marks) in the edges of adjacent hull planks, followed by the insertion of coaks, after which the planks were driven home with mallets. Much of the abundant caulking found in the plank seams must have also been inserted at this time, although some caulking deposits were due to later repairs. Some of the planks towards the ends of the ship were char-bent to the desired shape.

Before the first waterline wales were installed, ‘L’-shaped floor timbers were inserted in the hull. Notches cut in the upper edge of the strake below the single surviving wale timber, PS 13, coincide with the positions of the upper ends of ‘long arms’ of the floors. These features were likely caused during the shaping of the strake below the first wale during construction. Cutting the upper edge of the strake flush with an adze would have been relatively simple unless floor timbers were already in place in which case the excess wood at frame positions would have necessarily been removed with a chisel. Such a method probably left these notches in the hull planking, which were later caulked over. It is important to note that there are no clear indications that any floor timbers were installed in the hull before this stage of construction; evidence such as score marks and adzed depressions on the inner faces of hull planks at the locations of floor timbers, coaks located under floor positions, and irregularities in the shaping of the floors themselves indicate that the frame timbers all played a ‘passive’ role in the design of the lower hull from the keel to the first or waterline wales. From the waterline to the caprail, however, pre-erected futtocks and top timbers determined the shape of the hull. Above the waterline, coaks were used as planking edge fasteners only at the scarf ends of hull planks. Through-beams, stanchions, and other internal structures were installed in the later stages of construction as well.

Many of the differences between the construction features of YK 14 and other Late Roman and Byzantine-era ships excavated elsewhere in the Mediterranean could be explained by a local origin for the ship in the Sea of Marmara region. YK 14 was built with light scantling and with relatively little longitudinal reinforcement in the hull in comparison to contemporaneous ships excavated in other areas of the eastern Mediterranean. This suggests that the ship was designed for fair-weather coastal sailing and local use rather than sailing on the open sea.[943] It was also built with several types of timber which were available in the region around Constantinople, including Turkey oak, a species described in documentary sources since the Hellenistic and Roman periods as a species prone to rot. This problem appears to have been dealt with by using copious amounts of pine pitch on the hull combined with the occasional replacement of rotten or damaged sections of the hull.[944] The choice of Turkey oak, a tree species that tends to

[943] Laiou and Morrisson (2007, 81-3) define three levels of trade: local, regional, and interregional or long-distance trade. Local exchange consists of trade over distance “under 50 km on the land route or a day’s sailing in small ships that involved direct exchange between producers and consumers.” Regional trade involves “larger areas (from 50 to c. 300 km) and would involve transactions on a larger scale”, such as the transport of livestock from Bithynia and Paphlagonia to Constantinople. Long-distance or interregional trade, which was almost exclusively maritime, was conducted over longer distances (Laiou and Morrisson 2007, 81-3). Based on these definitions, YK 14 was likely used only for local or regional trade.
[944] Liphschitz and Pulak 2009, 170.

grow only 8-16 m tall, may have limited the size of timbers available for construction of YK 14 and other oak vessels from Yenikapı; individual planks and keel timbers in these ships rarely exceed six meters in length, and irregular, small-diameter timbers were often used for framing.[945] This design limitation was probably determined by cost and availability of timber; ship construction using an adequate, locally available wood must have been less expensive and therefore preferable to importing timber of better quality.[946]

Other economizing measures are apparent in YK 14's hull, including the relatively small number of iron fasteners and evidence of extensive repairs. The use of coaks as edge fasteners may be another cost-cutting yet functional construction method. Joining planks with coaks allows close control of the shape of a ship's hull using very simple shell-first construction methods. Regularly-spaced coaks may also have provided some longitudinal strength to the completed ship, perhaps serving as a cheap alternative to installing heavier longitudinal timbers in the hull. The methods used to construct YK 14 are rooted in an ancient tradition of shell-first shipbuilding, yet these methods appear to have been simplified as far as possible for the sake of efficiency. Many scholars have associated the adoption of skeleton-first shipbuilding with a need to build ships more quickly and efficiently. The hull of YK 14 seems to be an example of a ship built with efficiency and cost as overriding concerns. This goal was pursued only partially through the use of 'active' framing, in the more easily-constructed upper part of the hull, and

[945] Liphschitz and Pulak 2009, 170-71.
[946] Liphschitz and Pulak 2009, 170.

partly through further simplification, rather than abandonment, of traditional Mediterranean shell-first construction methods. This economizing trend in Late Roman and Byzantine shell-first construction was first noted in earlier studies of the Byzantine ships from Yassıada, Turkey, dating to the late fourth and seventh centuries C.E., and the Dramont F shipwreck from the southern coast of France; a recent study (Pomey et al. 2012) establishes that this was a Mediterranean-wide phenomenon. At Yenikapı, this trend seems to have been taken to an extreme not seen in earlier ships or in seagoing ships of the same period.

Although the description of YK 14 as a coaster for local use should be treated with some caution due to the nature of Mediterranean sailing conditions—a small vessel engaged in *cabotage* could have traveled over great distances during the fair-weather sailing season—there are nonetheless clear structural differences in the hull construction of YK 14 and other Byzantine vessels. The Serçe Limanı and Bozburun ships are roughly the same size as YK 14; however, they are more heavily built, with larger frames and longitudinal timbers, including a keelson on the Serçe Limanı ship. The timber types used in their hulls also suggest an origin elsewhere in the Byzantine Empire, perhaps in the Aegean or along the southern coast of Asia Minor, although many other aspects of their construction are similar to those used on YK 14.[947] The differences appear to lie in

[947] The timber types used in the construction of the Serçe Limanı ship (primarily Turkish pine, *Pinus brutia*, and European cypress, *Cupressus sempervirens*), suggest an origin south of the Sea of Marmara in the Aegean or south coast of Anatolia; (van Doorninck 2012, 132. For the distribution of these species in Anatolia and the eastern Mediterranean, see Davis 1975, 5:72-8). Hocker (1998, 9) notes that the wood species used for the construction of the Bozburun ship, which include oak (possibly *Quercus ilex*) and pine (probably *Pinus brutia*) are available locally along the southwest coast of Anatolia.

the function of these vessels: the Serçe Limanı ship was certainly used for long-distance trade based on its cargo and the possessions of its crew, and the heavily-built Bozburun ship is well-suited for such commerce as well. YK 14, on the other hand, appears to have been too lightly built for regular open-sea voyages, and was perhaps better suited for fair-weather coastal sailing in relatively sheltered waters such as the Sea of Marmara.

The discovery of YK 14 and the other mixed-construction vessels from Yenikapı are an important new addition to the history of maritime technology in the Mediterranean. The Yenikapı ships show that the shell-first construction of the Classical era continued in the Mediterranean in a modified form until the end of the first millennium C.E. The survival of this construction tradition in the immediate hinterland of the Byzantine Empire's capital, rather than a less politically and economically prominent area, clearly indicates the importance of this shipbuilding technology. The detailed excavation and study of dozens of shipwrecks from Yenikapı since 2005 attest to the scale of the scale of this industry and establish that ships like YK 14 were very common at Constantinople in the ninth and tenth centuries. At the very least, YK 14 is the product of a significant local shipbuilding tradition probably centered on the Sea of Marmara, where use of mixed-construction techniques was confined to smaller local craft. Based on its importance to the functioning of the capital, however, it is certainly possible that this shipbuilding tradition was influential throughout the Byzantine Empire in the design of ships for various purposes. Certain aspects of YK 14's construction, such as its framing pattern and hull shape, are suitable for ship construction using frame-first methods as well as mixed shell/skeleton construction methods, as demonstrated by the Serçe Limanı ship's frame-first hull. While the Byzantine shipbuilding tradition represented at Yenikapı was conservative in many respects, it also shows a great deal of adaptability to the changing economic, political, and environmental circumstances in the Mediterranean between the seventh and tenth centuries. The possibility that this shipbuilding tradition influenced the development of frame-first ship construction in the Mediterranean should not be ruled out.

REFERENCES CITED[948]

1) Ancient Primary Sources

Babbitt, F. C., trans. 1972. *Plutarch: Moralia*. Vol. IV. LCL 305. Cambridge, MA: Harvard University Press.

Cameron, A., trans. 1976. *Flavius Cresconius Corippus: In Laudem Iustini Augusti Minoris*. London: Athlone Press/University of London.

Dewing, H. B., trans. 1978. *Procopius: History of the Wars*, Volume 2. LCL 217. Cambridge, MA: Harvard University Press.

Dewing, H. B., trans. 1996. *Procopius: Buildings*. Cambridge, MA: Harvard University Press.

Hort, A., trans. 1916. *Theophrastus: Enquiry Into Plants*. Volume 1. Cambridge, MA: Harvard University Press.

Milner, N. P., trans. 1993. *Vegetius: Epitome of Military Science*. Translated Texts for Historians Volume 16. Melksham, United Kingdom: Liverpool University Press.

Pharr, C., trans. 1952. *The Theodosian Code and Novels and the Sirmondian Constitution*s. Princeton, NJ: Princeton University Press.

Rackham, H., ed. and trans. 2000. *Pliny: Natural History*. LCL 370. Cambridge, MA: Harvard University Press.

de Sélincourt, A., ed. and trans. 2003. *Herodotus: The Histories*. London: Penguin Books.

[948] Abbreviations are from the bibliographical format of the *American Journal of Archaeology*.

Shuckburgh, E. S., trans. 1962. *Polybius: Histories*. Bloomington, UK. Original edition, London: MacMillan, 1889.

Woodman, A. J., trans. 2004. *The Annals of Tacitus*. Indianapolis: Hackett Publishing Company.

2) Medieval Primary Sources

Ashburner, W., ed. and trans. 1976. *The Rhodian Sea-Law*. Darmstadt, Germany: Wilhelm Weihert KG. Original edition, Oxford: Clarendon Press, 1909.

Dalby, A., trans. 2011. *Geoponika*. Devon, United Kingdom: Prospect Books.

Dennis, G. T., ed. and trans. 2008. *Three Byzantine Military Treatises*. Washington, DC: Dumbarton Oaks.

Dennis, G. T., ed. and trans. 2010. *The* Taktika *of Leo VI. Text, Translation, and Commentary*. Washington, DC: Dumbarton Oaks.

Freshfield, E. H., trans. 1938a. *Roman Law in the Later Roman Empire. Byzantine Guilds, Professional and Commercial: Ordinances of Leo VI, c. 895, from the Book of the Eparch*. Cambridge, United Kingdom: Cambridge University Press.

Freshfield, E. H., trans. 1938b. *A Manual of Eastern Roman Law, The* Procheiros Nomos, *Published by the Emperor Basil I at Constantinople Between 867 and 879 A.D.* Cambridge, United Kingdom: Cambridge University Press.

Geanakoplos, D. J., ed. and trans. 1986. *Byzantium: Church, Society, and Civilization Seen Through Contemporary Eyes*. Chicago: University of Chicago Press.

Kaldellis, A., and D. Krallis, trans. 2012. *The History. Michael Attaleiates*. Dumbarton Oaks Medieval Library 16. Cambridge, MA: Harvard University Press.

Lopez, R. S., and I. W. Raymond, ed. and trans. 2001. *Medieval Trade in the Mediterranean World: Illustrative Documents*. New York: Columbia University Press.

Lunde, P., and C. Stone, ed. and trans. 1989. *The Meadows of Gold. The Abbasids*, by Mas'udi. London: Kegan Paul International.

Mango, C., and R. Scott, trans. 1997. *The Chronicle of Theophanes Confessor. Byzantine and Near Eastern History AD 284-813*. Oxford, United Kingdom: Clarendon Press.

Minorsky, V., trans. 1937. *Ḥudūd al-'Ālam, 'The Regions of the World': a Persian Geography*. London: Oxford University Press.

Moravcsik, G., and J. H. Jenkins, ed. and trans. 2008. *Constantine Porphyrogenitus*: De Administrando Imperio. Washington DC: Dumbarton Oaks.

Sewter, E. R. A., trans. 1966. *Fourteen Byzantine Rulers: The* Chronographia *of Michael Psellus*. London: Penguin Books.

Smith, C., trans. 2008. *Joinville and Villehardouin: Chronicles of the Crusades*. London: Penguin Books.

Squatriti, P., trans. 2007. *The Complete Works of Liutprand of Cremona*. Washington, D C: The Catholic University of America Press.

Sullivan, D. F., trans. 2000. *Siegecraft: Two Tenth-Century Instructional Manuals by "Heron of Byzantium*." Washington, DC: Dumbarton Oaks.

Vasiliev, A. A., and M. Canard, ed. and trans. 1950. *Byzance et les arabes*. Tome II. *La Dynastie Macédonienne (867-959)*. Deuxième partie: *Extraits des sources arabes*. Brussels, Belgium: Éditions de l'Institut de Phililogie et d'Histoire Orientales et Slaves.

Vinson, M. P., ed. and trans. 1985. *The Correspondence of Leo, Metropolitan of Synada and Syncellus*. Washington DC: Dumbarton Oaks.

Whitby, Michael., and Mary Whitby, trans. 1989. *Chronicon Paschale 284-628 AD*. Translated Texts for Historians Volume 7. Liverpool, United Kingdom: Liverpool University Press.

Witakowski, W., ed. and trans. 1996. *Pseudo-Dionysus of Tel-Mahre: Chronicle (Known also as the Chronicle of Zuqnin), Part III*. Translated Texts for Historians Vol. 22. Liverpool, United Kingdom: Liverpool University Press.

3) Secondary Sources

Adam, P., and C. Villain-Gandossi. 1989. "Byzantine Ships. Iconography and Archaeology Sources." In *Medieval Ships and the Birth of Technological Societies,* Volume II: *The Mediterranean Area,* edited by C. Villain-Gandossi, S. Busuttil, and P. Adam, 17-38. Malta: European Coordination Centre for Research and Documentation in Social Sciences/Foundation for International Studies.

Agius, D. A. 2002. *In the Wake of the Dhow*. Reading, United Kingdom: Ithaca Press.

Agius, D. A. 2008. *Classic Ships of Islam from Mesopotamia to the Indian Ocean*. Leiden, Netherlands: E. J. Brill.

Ahrweiler, H. 1966. *Byzance et la mer: la marine de guerre, la politique et les institutions maritimes de byzance aux VIIe-XVe siècles*. Paris: Presses Universitaires de France.

Akkemik, Ü. 2008. “Identification of Timbers from Yenikapı 12 Shipwreck.” In *The ‘Old Ships’ of the ‘New Gate,’* edited by U. Kocabaş, 203-11. Istanbul, Turkey: Zero Production, Ltd.

van Alfen, P. G. 1996. “New Light on the 7th-Century Yassi Ada Shipwreck: Capacities and Standard Sizes of LRA1 Amphoras.” *JRA* 9:189-213.

al-Hijji, Y. Y. 2001. *The Art of Dhow-Building in Kuwait*. London: London Center of Arab Studies.

al-Said, F. 1979. *Oman: A Seafaring Nation*. London: Michael Rice & Company Ltd./ Ministry of Information and Culture of the Sultanate of Oman.

Alertz, U. 2003. “The Venetian Merchant Galley and the System of *Partisoni*—Initial Steps Towards Modern Ship Design.” In *Boats, Ships, and Shipyards: Proceedings of the Ninth International Symposium on Boat and Ship Archaeology, Venice 2000 (ISBSA 9)*, edited by C. Beltrame, 212-21. Oxford, United Kingdom: Oxbow Books.

Alston, R. C. 1972 (ed.). *Henry Mainwayring’s The Seaman’s Dictionary, 1644*. Menston, United Kingdom: The Scholar Press Ltd. Original edition: London, 1644, John Bellamy.

Angold, M. 1985. “The Shaping of the Medieval Byzantine ‘City.’” *Byzantinische Forschungen* 10:1-37.

Angold, M. 1997. *The Byzantine Empire, 1025-1204: A Political History*. London: Longman.

Antoniadis-Bibicou, H. 1966. *Études d'histoire maritime de Byzance a propos du "Thème des caravisiens."* Paris: S.E.V.P.E.N.

Asal, R. 2007. "Commerce in Istanbul and the Port of Theodosius." In *Istanbul: 8,000 Years Brought to Daylight: Marmaray, Metro, Sultanahmet Excavations*, edited by Z. Kızıltan, 180-89. Istanbul, Turkey: Vehbi Koç Vakfı.

Asal, R. 2010. "Theodosian Harbour and Sea Trade in Byzantine Istanbul." In *Istanbul Archaeological Museums Proceedings of the 1st Symposium on Marmaray-Metro Salvage Excavations, 5th-6th May 2008*, edited by U. Kocabaş, 153-60. Istanbul, Turkey: Istanbul Archaeological Museums/Epsilon.

Auzépy, M.-F. 2008. "State of Emergency (700-850)." In *The Cambridge History of the Byzantine Empire, c. 500-1492*, Volume I, edited by J. Shepard, 251-91. Cambridge, United Kingdom: Cambridge University Press.

Avramea, A. 2002. "Land and Sea Communications, Fourth-Fifteenth Centuries." In *The Economic History of Byzantium from the Seventh Through the Fifteenth Century*, edited by A. E. Laiou, 57-90. Dumbarton Oaks Series No. 39, Vol. 1-3. Washington, DC: Dumbarton Oaks.

Ballard, R. D., F. T. Hiebert, D. F. Coleman, C. Ward, J. S. Smith, K. Willis, B. Foley, K. Croff, C. Major, and F. Torre. 2001. "Deepwater Archaeology of the Black Sea: The 2000 Season at Sinop, Turkey." *AJA* 105.4:607-23.

Barkai, O. 2009. “The Tantura F Shipwreck.” In *Between the Seas: Transfer and Exchange in Nautical Technology: Proceedings of the Eleventh International Symposium on Boat and Ship Archaeology, Mainz 2006, ISBSA 11*, edited by R. Bockius, 25-31. Mainz, Germany: Römisches-Germanisches Zentralmuseum.

Barkai, O. 2010. “The Tantura F Shipwreck.” In *Transferts technologiques en architecture navale Méditerranéenne de l’antiquité aux temps Modernes: identité technique et identité culturelle. Actes de la Table Ronde d’Istanbul, 19-22 mai 2007*, edited by P. Pomey, 97-106. Varia Anatolica XX. Paris: De Boccard/Institut Français D’Etudes Anatoliennes George- Dumezil.

Barkai, O., and Y. Kahanov. 2007. “The Tantura F Shipwreck, Israel.” *IJNA* 36.1:21-31.

Barkai, O., Y. Kahanov, and M. Avissar. 2010. “The Tantura F Shipwreck: The Ceramic Material.” *Levant* 42.1:88-101.

Barker, R. 1991. “Design in the Dockyards, about 1600.” In *Carvel Construction Technique*; *5th International Symposium for Boat and Ship Archaeology, Amsterdam, September 1988*, edited by R. Reinders and K. Paul, 61-9. Oxford, United Kingdom: Oxbow Books.

Barreveld, W. H. 1993. *Date Palm Products*. FAO Agricultural Services Bulletin 101. Rome: Food and Agriculture Organization of the United Nations.

Başaran, S., U. Kocabaş, I. Kocabaş, and R. Yılmaz. 2007. “Istanbul University Yenikapı Byzantium Shipwrecks Project: Documentation, Lifting, Conservation, and Reconstruction.” In *Istanbul Archaeological Museums Proceedings of the 1st Symposium on Marmaray-Metro Salvage Excavations, 5th-6th May 2008,* edited by U. Kocabaş, 190-95. Istanbul, Turkey: Istanbul Archaeological Museums/Epsilon.

Başaran, S., and U. Kocabaş. 2008. "From Theodosian Harbour to Yenikapı Shipwrecks." *Colloquium Anatolicum* 7:1-22.

Basch, L. 1972. "Ancient Wrecks and the Archaeology of Ships." *IJNA* 1:1-58.

Basch, L. 1989. "The Way to the Lateen Sail." *Mariner's Mirror* 75.4:328-32.

Basch, L. 1991a. "Un navire marchand Byzantin à Corinthe." *Neptunia* 181.1:14-21.

Basch, L. 1991b. "La felouque des Kellia. Un navire de mer à voile latine en Egypte au VIIe siècle de notre ère." *Neptunia* 183:2-10.

Basch, L. 1993. "Navires et bateaux coptes: ètat de la question en 1991." *Graeco-Arabica* 5:23-62.

Basch, L. 1997. "L'apparition de la voile latine en Méditerranée." In *Techniques et économie antiques et médiévales. Le temps de l'innovation. Colloque d'Aix-en-Provence*, edited by D. Garcia and D. Meeks, 214-23. Paris: Errance.

Basch, L. 2001. "La voile latine, son origine, son evolution et ses parentés arabes." In *Tropis VI, 6th International Symposium on Ship Construction in Antiquity, Lamia 1996, Proceedings*, edited by H. Tzalas, 55-85. Athens, Greece: Hellenic Institute for the Preservation of Nautical Tradition.

Bass, G. F. 1974. "Turkey: Survey for Shipwrecks, 1973." *IJNA* 3.2:335-38.

Bass, G. F., and F. H. Van Doorminck. 1978. "An 11th Century Shipwreck at Serçe Liman, Turkey." *IJNA* 7.2:119-32.

Bass, G. F., and F. H. Van Doorninck. 1982. *Yassi Ada: A Seventh-Century Byzantine Shipwreck*. College Station, TX: Texas A & M University Press.

Bass, G. F., R. H. Brill, and S. D. Matthews. 2009. *Serçe Limanı.* Volume II. *The Glass of an Eleventh-Century Shipwreck.* College Station, TX: Texas A&M University Press.

Bass, G. F., S. D. Matthews, and J. R. Steffy. 2004. *Serçe Limanı: An Eleventh Century Shipwreck.* Volume I: *The Ship and Its Anchorage, Crew, and Passengers*. College Station, TX: Texas A&M University Press.

Beckerleg, S. 2002. "Continuity and Adaptation by Contemporary Swahili Boatbuilders in Kenya." In *Ships and The Development of Maritime Technology in the Indian Ocean*, edited by D. Parkin and R. Barnes, 259-77. London: Routledge.

Bellabarba, S. 1988. "The Square-rigged Ship of the *Fabrica di Galera* Manuscript." *Mariner's Mirror* 74.2:113-30.

Bellabarba, S., and E. Guerreri. 2002. *Vele italiane della costa occidentale dal medioevo al novecento*. Milan: Editore Ulrico Hoepli.

Beltrame, C. 2009. "A New View of the Interpretation of the Presumed Medieval Po Delta Wrecks, Italy." *IJNA* 38.2:412-17.

Berger, A. 1993. "Der Langa Bostani in Istanbul." *Istanbuler Mitteilungen* 43:467-77.

Berti, F. 1990, ed. *Fortuna Maris: La nave romana di Comacchio*. Bologna, Italy: Nuova Alfa Editoriale.

Black, E., and D. Samuel. 1991. "What Were the Sails Made Of?" *Mariner's Mirror* 77.3:217-26.

Blanchette, R. A. 2000. “A Review of Microbial Deterioration Found in Archaeological Wood from Different Environments.” *International Biodeterioration & Biodegradation* 46:189-204.

Blöndal, S. 1978. *The Varangians of Byzantium*. Translated by B. S. Benedikz. Cambridge, United Kingdom: Cambridge University Press.

Bockius, R. 2006a. “Coating, sheathing, caulking and luting in ancient shipbuilding.” In *Connected by the Sea: Proceedings of the Tenth International Symposiun on Boat and Ship Archaeology, Roskilde 2003 (ISBSA 10)*, edited by L. Blue, F. Hocker, and A. Englebert, 117-22. Oxford, United Kingdom: Oxbow Books.

Bockius 2006b. *Die Spätrömischen Schiffwracks auz Mainz*. Monographien des Römisch-Germanischen Zentralmuseums Band 67. Mainz, Germany: Verlag des Römisch-Germanischen Zentralsmuseums.

Bockius, R. 2009. “Markings and Pegs: Clues to Geoemtrical Procedures of Roman Naval Architecture?” In *Creating Shapes in Civil and Naval Architecture: A Cross-Disciplinary Comparison*, edited by H. Nowacki and W. Lefevre, 73-92. Leiden, Netherlands: History of Sciences and Medicine Library.

Bondioli, M. 2009. “Early Shipbuilding Records and the Book of Michael of Rhodes.” In *The Book of Michael of Rhodes: A Fifteenth Century Maritime Manuscript*. Volume 3: Studies, edited by P. O. Long, 243-80. Cambridge, MA: MIT Press.

Bonino, M. 1978. “Lateen-rigged medieval ships. New evidence from wrecks in the Po Delta (Italy) and notes on pictorial and other documents.” *IJNA* 7.1:9-28.

Bound, M. 1991. *The Giglio Wreck: A Wreck of the Archaic Period (c. 600 BC) off the Tuscan Island of Giglio. An Account of its Discovery and Excavation: a Review of the Main Finds*. Enalia Supplement 1. Athens, Greece: Hellenic Institute of Marine Archaeology.

Bouras, C. 2002a. "Aspects of the Byzantine City, Eighth-Fifteenth Centuries." In *The Economic History of Byzantium from the Seventh Through the Fifteenth Century*, edited by A. E. Laiou, 497-528. Dumbarton Oaks Series No. 39. Washington, DC: Dumbarton Oaks.

Bouras, C. 2002b. "Master Craftsmen, Craftsmen, and Building Activities in Byzantium." In *The Economic History of Byzantium, from the Seventh to the Fifteenth Century,* edited by A. Laiou, 539-54. Dumbarton Oaks Series No. 39. Washington, DC: Dumbarton Oaks.

Braudel, F. 1995. The *Mediterranean and the Mediterranean World in the Age of Philip II,* Vols. 1-2. Translated by Siân Reynolds. Berkeley, CA: University of California Press.

Brindley, H. H. 1926. "Early Pictures of Lateen Sails." *Mariner's Mirror* 12.1:9-22.

Browning, R. 1993. "The City and the Sea." In *The Greeks and the Sea,* edited by S. Vryonis, 97-112. New Rochelle, NY: Aristide D. Caratzas.

Bruzelius, L. 2012. "The Maritime History Virtual Archives." www.bruzelius .info/Nautica/Shipbiulding/Fastening/Fastening.html, (February 2013).

Bryer, A. 1986. "Byzantine Agricultural Implements: The Evidence of Medieval Illustrations of Hesiod's Works and Days." *ABSA* 81:45-80.

Burningham, N. 2000. “Indonesian quarter-rudder mountings.” *IJNA* 29.1:100-19.

Byrd, K., trans. 2008. *Pierre Gilles’ Constantinople*. New York: Italica Press.

Cameron, A. 1968. “Notes on the Sophiae, the Sophianae, and the Harbour of Sophia.” *Byzantion* 37: 11-20.

Campbell, I. C. 1995. “The Lateen Sail in World History.” *Journal of World History* 6.1:1-23.

Carr, A. W. 2001. “Icons and the Object of Pilgrimage in Middle Byzantine Constantinople.” *DOP* 56:75-92.

Carre, M.-B., and M.-P. Jézégou. 1984. “Pompes à Chapelet sur des Navires de L’Antiquité et du Début du Moyen Âge.” *Archaeonautica* 4:115-43.

Casson, L. 1952. “Bishop Synesius’ Voyage to Cyrene.” *American Neptune* 12:294-96.

Casson, L. 1956. “Fore-and-aft Sails in the Ancient World.” *Mariner’s Mirror* 42.1:3-5.

Casson, L. 1960. “The Sprit-Rig in the Ancient World.” *Mariner’s Mirror* 46.1:16.

Casson, L. 1971. “Origin of the Lateen.” *American Neptune* 31:49-71.

Casson, L. 1980. “The Role of the State in the Roman Grain Trade.” In *The Seaborne Commerce of Ancient Rome: Studies in Archaeology and History*, edited by J. H. D’Arms and E. C. Kopff, 21-34. Memoirs of the American Academy in Rome, vol. XXXVI. Rome: American Academy in Rome.

Casson, L. 1995. *Ships and Seamanship in the Ancient World*. Princeton, NJ: Princeton University Press.

Catling, D., and J. Grayson. 1982. *Identification of Vegetable Fibers*. London: Chapman and Hall.

Charlton, W. H. 1995. "The Rope." *INA Quarterly* 22.2:17.

Charlton, W. H. 1996. "Rope and the Art of Knot-Tying in the Seafaring of the Ancient Eastern Mediterranean." Master's Thesis, Texas A&M University.

Christiansen, A. E. 1972. "Boatbuilding Tools and the Process of Learning." In *Ships and Shipyards, Sailors and Fishermen. Introduction to Maritime Ethnology*, edited by O. Hasslöf, H. Henningsen, and A. E. Christiansen, 235-59. Copenhagen, Denmark: Copenhagen University Press.

Christides, V. 2001. "Fireproofing of War Machines, Ships, and Garments." In *Tropis VI, Proceedings of the 6th International Symposium on Ship Construction in Antiquity, Lamia, 28, 29, 30 August 1996*, 135-41. Athens, Greece: Hellenic Institute for the Preservation of Nautical Tradition.

Coates, J. 1985. "Hogging or 'Breaking' of Frame-Built Wooden Ships. A Field for Investigation?" *Mariner's Mirror* 71.4: 437-42.

Coates, J. 2001. "Planking Tenons in Ancient Mediterranean Ships Built Shell First." In In *Tropis VI: Proceedings of the 6th International Symposium on Ship Construction in Antiquity, Lamia, 28, 29, 30 August 1996*, edited by H. Tzalas, 153-70. Athens, Greece: Hellenic Institute for the Preservation of Nautical Tradition.

Connan, J., and A. Nissenbaum. 2003. "Conifer Tar on the Keel and Hull Planking of the Ma'agan Mikhael Ship (Israel, 5th Century BC): Identification and Comparison with Natural Products and Artifacts Employed in Boat Construction." *JAS* 30: 709-19.

Croke, B. 2005. “Justinian’s Constantinople.” In *The Cambridge Companion to the Age of Justinian*, edited by M. Maas, 60-86. Cambridge, United Kingdom: Cambridge University Press.

Crow, J. 2001. “Fortifications and Urbanism in Late Antiquity: Thessaloniki and Other Eastern Cities.” 89-105. *JRA* Supplement 21:91-107.

Crow, J., 2002. “Late Antique Cities in Eastern Thrace (Europa).” In *The Roman and Late Roman City: The International Conference Veliko Tarnovo, 26-30 July 2000*, edited by L. Slokoska and A. Poulter, 342-51. Sofia, Bulgaria: Professor Marin Drinov Academic Publishing House.

Crow, J. 2007. “The infrastructures of a great city: Earth, Walls and Water in late antique Constantinople.” In *Technology in Transition, AD 300-650*, edited by L. Lavan, A. Sarantis, and E. Zanini, 251-85. Late Antique Archaeology Vol. 4. Leiden, Netherlands: Brill.

Crow, J., and R. Bayliss. 2004. “Water for the Queen of Cities: a review of recent research into the Byzantine and early Ottoman water supply of Constantinople.” *Basilissa* 1:27-49.

Crow, J., J. Bardill, and R. Bayliss. 2008. *The Water Supply of Byzantine Constantinople*. Journal of Roman Studies Monograph 11. London: Society for the Promotion of Roman Studies.

Crumlin-Pedersen, O., and O. Olsen, eds. 2002. *The Skuldelev Ships.* Volume I. *Topography, Archaeology, History, Conservation, and Display*. Roskilde, Denmark: The Viking Ship Museum in Roskilde.

Çelik, Ü. 2010. "The Marmaray Project." In *Istanbul Archaeological Museums Proceedings of the 1st Symposium on Marmaray-Metro Salvage Excavations, 5th-6th May 2008*, edited by U. Kocabaş, 65-75. Istanbul, Turkey: Istanbul Archaeological Museums/Epsilon.

Çölmekçi, S. 2007. "Technology in Yenikapı." In *Istanbul: 8,000 Years Brought to Daylight: Marmaray, Metro, Sultanahmet Excavations*, edited by Z. Kızıltan, 236-41. Istanbul, Turkey: Vehbi Koç Vakfı.

Damianidis, K. 1991. "Planking Up a Carvel Boat in the Aegean." In *Carvel Construction Technique. Fifth International Symposium on Boat and Ship Archaeology, Amsterdam 1988*, edited by R. Reinders and K. Paul, 97-102. Oxbow Monographs 12. Oxford, United Kingdom: Oxbow Books.

Damianidis, K. 1999. "'Pereme Kutugu' from Inebolu: The Last 'Shell-First' Construction Survived in the Black Sea." In *Tropis V: 5th International Symposium on Ship Construction in Antiquity. Proceedings Nauplia, 26, 27, 28 August 1993*, edited by H. Tzalas, 129-34. Athens: Hellenic Institute for the Preservation of Nautical Tradition.

Dagron, G. 2002. "The Urban Economy, Seventh-Twelfth Centuries." In *The Economic History of Byzantium from the Seventh Through the Fifteenth Century*, edited by A. E. Laiou, 393-461. Dumbarton Oaks Series No. 39. Washington, DC: Dumbarton Oaks.

van Dam, R. 2010. *Rome and Constantinople: Rewriting History during Late Antiquity*. Waco, TX: Baylor University Press.

Danis, D. M. 2002. “An Analysis of the Galley Ware from a Ninth-Century Shipwreck at Bozburun, Turkey.” Unpublished Master’s Thesis, Texas A&M University.

Dark, K. R. 2001. *Byzantine Pottery*. Charleston, SC: Tempus Publishing.

Dark, K. R. 2004. “The New Post Office Site in Istanbul and the North-Eastern Harbour of Byzantine Constantinople.” *IJNA* 33.2:315-19.

Dark, K. R. 2005. “The Eastern Harbours of Byzantine Constantinople.” *Byzantion* 75:152-63.

Darrah, R. 1982. “Working Unseasoned Oak.” In *Woodworking Techniques Before 1500*, edited by S. McGrail, 219-30. National Maritime, Greenwich, Archaeological Series No. 7. BAR-IS 129. Oxford, United Kingdom: British Archaeological Reports.

Davis, D. L. 2001. “Navigation in the Ancient Eastern Mediterranean.” Master’s Thesis, Texas A&M University.

Davis, D. L. 2009. “Commercial Navigation in the Greek and Roman World.” Ph.D. diss., University of Texas, Austin.

Davis, P. H., ed. 1967. *Flora of Turkey and the East Aegean Islands*. Vol. 2. Edinburgh, United Kingdom: University of Edinburgh Press.

Davis, P. H., ed. 1975. *Flora of Turkey and the East Aegean Islands*, Vol. 5. Edinburgh, United Kingdom: University of Edinburgh Press.

Davis, P. H., ed. 1978. *Flora of Turkey and the East Aegean Islands*. Vol. 6. Edinburgh, United Kingdom: University of Edinburgh Press.

Davis, P. H., ed. 1982. *Flora of Turkey and the East Aegean Islands*. Vol. 7. Edinburgh, United Kingdom: University of Edinburgh Press.

Decker, M. 2009. "Export Wine Trade to West and East." In *Byzantine Trade, 4th-12th Centuries. The Archaeology of Local, Regional, and Interregional Trade*, edited by M. M. Mango, 239-52. Papers of the Thirty-Eighth Spring Symposium of Byzantine Studies, St. John's College, University of Oxford, March 2004. Burlington, VT: Ashgate Publishing.

Dimmock, L. 1946. "The Lateen Rig." *Mariner's Mirror* 32.1:35-41.

DLH Marmaray Division Directorate. 2004, 29 November. *Marmaray Project Facts and Figures*. http://www.marmaray.com/html/technical.html (23 March 2011).

van Doorninck, Jr., F. H. 1972. "Byzantium, Mistress of the Sea: 330-641." In *A History of Seafaring Based on Underwater Archaeology*, edited by G. F. Bass, 133-58. London: Thames and Hudson.

van Doorninck, F. H. 1974. "A Brief Note on Basch's Remarks on the 7th Century Byzantine Wreck at Yassi Ada." *IJNA* 3.2:310-11.

van Doorninck, F. H. 1976. "The 4th century wreck at Yassi Ada. An interim report on the hull." *IJNA* 5:115-31.

Van Doorninck, F. H. 1982. "The Hull Remains." In *Yassı Ada: A Seventh-Century Shipwreck*. Volume I, by G. F. Bass and F. H. van Doorninck, 32-64. College Station, TX: Texas A&M University Press.

van Doorninck, F. H. 1989. “The Cargo Amphorae on the 7th Century Yassi Ada and the 11th Century Serçe Limanı Shipwrecks: Two Examples of a Reuse of Byzantine Amphoras as Transport Jars.” *Recherches sur la ceramique byzantine* 18:247-57.

van Doorninck, F. H. 1993. “Giving Good Weight in Eleventh-Century Byzantium: The Metrology of the Glass Wreck Amphoras.” *INA Quarterly* 20.2:8-12.

van Doorninck, F. H. 2002a. “Byzantine Shipwrecks.” In *The Economic History of Byzantium: from the Seventh to the Fifteenth Century*, vol. 3, edited by A. E. Laiou, 899-905. Dumbarton Oaks Series No. 39. Washington, DC: Dumbarton Oaks Research Library and Collection.

van Doorninck, F. V. 2002b. “The Byzantine Ship at Serçe Limanı: an Example of Small-Scale Maritime Commerce with Fatimid Syria in the Early Eleventh Century.” In *Travel in the Byzantine World*, edited by R. Macrides, 137-48. Society for the Promotion of Byzantine Studies Publications 10. Aldershot, United Kingdom: Ashgate Publishing, Ltd.

van Doorninck, F. H. 2012. “Ethnicity and Sphere of Activity of the Crew of the 11th Century Serçe Limanı Ship: Some Tentative Observations.” In *Between Continents: Proceedings of the Twelfth Symposium on Boat and Ship Archaeology, Istanbul 2009 (ISBSA 12)*, edited by N. Günsenin, 127-34. Istanbul, Turkey: Zero Prodüksiyon.

Dumas, F. 1964. *Épaves antiques*. Paris: G.-P. Maisonneuve et Larose.

Duncan-Jones, R. P. 1976. “The Size of the *Modius Castrensis*.” *ZPE* 21:53-62.

Duncan-Jones, R. 1982. *The Economy of the Roman Empire: Quantitative Studies*. Cambridge, United Kingdom: Cambridge University Press.

Dunn, A. 1992. "The Exploitation and Control of Woodland and Scrubland in the Byzantine World." *Byzantine and Modern Greek Studies* 16:235-98.

Durliat, J. 1995. "L'approvisionnement de Constantinople." In *Constantinople and Its Hinterland*, edited by C. Mango and G. Dagron, 19-33. Aldershot, United Kingdom: Ashgate Publishing, Ltd.

Edmonson, J. C. 1989. "Mining in the Later Roman Empire and Beyond: Continuity or Disruption?" *JRS* 79:84-102.

El Cheikh, N. M. 2004. *Byzantium Viewed by the Arabs*. Cambridge, MA: Harvard University Press.

Eyigün, Y. 2010. "Istanbul Metro Construction Project Between Yenikapı and Unkapanı: Yenikapı Station." In *Istanbul Archaeological Museums Proceedings of the 1st Symposium on Marmaray-Metro Salvage Excavations, 5th-6th May 2008*, edited by U. Kocabaş, 53-63. Istanbul, Turkey: Istanbul Archaeological Museums/Epsilon.

Fabre, D. 2011. "The Shipwrecks of Heraclion-Thonis: a Preliminary Study." In *Maritime Archaeology and Ancient Trade in the Mediterranean*, edited by D. Robinson and A. Wilson, 13-32. Oxford Centre for Maritime Archaeology: Monograph 6. Oxford, United Kingdom: Oxford Centre for Maritime Archaeology.

Ferroni, A. M., and C. Meucci 1995/1996. “I due relitti arabo-normanni di Marsala.” *Bollettino di archeologia subacquea* II-III, n. 1-2:283-350.

Finderup, T. 2006. “History Written in Tool Marks.” In *Connected by the Sea: Proceedings of the Tenth International Symposium on Boat and Ship Archaeology, Roskilde 2003 (ISBSA 10)*, edited by L. Blue, F. Hocker, and A. Englebert, 21-6. Oxford, United Kingdom: Oxbow Books.

Flecker, M. 2007. “The South-China-Sea Tradition: the Hybrid Hulls of South-East Asia.” *IJNA* 36.1:75-90.

Flecker, M., and M. Foerster-Laures, F. 1986. “The Use of Tallow on the Hulls of Ships.” *IJNA* 15.2:161.

Foss, C. 1977. “Archaeology and the ‘Twenty Cities’ of Byzantine Asia.” *AJA* 81.4:469-86.

Foss, C. 1994. “The Lycian Coast in the Byzantine Age.” *DOP* 48:1-52.

Foss, C., and J. A. Scott. 2002. “Byzantine Sardis.” In *The Economic History of Byzantium from the Seventh Through the Fifteenth Century*, edited by A. E. Laiou, 615-22. Dumbarton Oaks Series No. 39. Washington, DC: Dumbarton Oaks.

Foss, C. 2010. *Ephesus After Antiquity: A Late Antique, Byzantine, and Turkish City.* Cambridge, United Kingdom: Cambridge University Press.

Friedman, Z., and L. Zoroglu. 2006. “Kelenderis Ship—Square or Lateen Sail?” *IJNA* 35.1:108-16.

Gassend, J.-M., B. Liou, and S. Ximénès. 1984. “L’épave de l’anse des Laurons (Martigues, Bouches-du-Rhône). *Archaeonautica* 4:75-105.

Gill, C. S., ed. 1982. *Steel’s Elements of Mastmaking, Sailmaking and Rigging,* by D. R. Steel. Largo, FL: Edward W. Sweetman, Co. Original edition, London, 1794.

Gillmer, T. C., and B. Johnson. 1982. *Introduction to Naval Architecture*. Annapolis, MD: Naval Institute Press.

Goitein, S. D. 1967. *A Mediterranean Society: The Jewish Communities of the Arab World as Portrayed in the Documents of the Cairo Geniza*. Volume 1: *Economic Foundations*. Berkeley, CA: University of California Press.

Gökçay, M. 2007a. “Architectural Finds from the Yenikapı Excavations.” In *Istanbul: 8,000 Years Brought to Daylight: Marmaray, Metro, Sultanahmet Excavations*, edited by Z. Kızıltan, 166-79. Istanbul, Turkey: Vehbi Koç Vakfı.

Gökçay, M. 2007b. “Yenikapı Kazıları: Bizans’ın Kıyısında.” *Arkeoatlas 2007*:120-27.

Gökçay, M. 2007c. “Eski Dünyanın “Yenikapısı” *Atlas* 172:92-8.

Gökçay, M. 2010. “Selected Wooden Finds from Yenikapı.” In *Istanbul Archaeological Museums Proceedings of the 1st Symposium on Marmaray-Metro Salvage Excavations, 5th-6th May 2008*, edited by U. Kocabaş, 135-52. Istanbul, Turkey: Istanbul Archaeological Museums/Epsilon.

Goldsworthy, A. 2009. *Why Rome Fell*. New Haven, CT: Yale University Press.

Goodman, W. L. 1964. *The History of Woodworking Tools*. New York: David McKay Company, Inc.

Gorham, L. D. 2000. “The Archaeobotany of the Bozburun Byzantine Shipwreck." Unpublished Ph.D. Dissertation, Texas A&M University.

Gorham, D. L., and V. M. Bryant. 2001. “Pollen, Phytoliths, and Other Microscopic Plant Remains in Underwater Archaeology.” *IJNA* 30.2:282-98.

Greene, E. S., M. L. Lawall, and M. E. Polzer. 2008. “Inconspicuous Consumption: The Sixth-Century B.C.E. Shipwreck at Pabuç Burnu, Turkey.” *AJA* 112:685-711.

Greenhill, B. 1971. *Boats and Boatmen of Pakistan*. Newton Abbot, United Kingdom: David & Charles Publishers Ltd.

Greenhill, B., and J. Morrisson. 1995. *The Archaeology of Boats and Ships: An Introduction*. London: Conway Maritime Press.

Guilland, R. 1950. “Le port palatin du Bucoleon.” *Byzantinoslavica* 11:187-206.

Guilland, R. 1969. *Études de Topographie de Constantinople Byzantine*. Berlin: Akademie-Verlag.

Günsenin, N. 2009. “”Ganos Wine and its Circulation in the 11th Century.” In *Byzantine Trade, 4th-12th Centuries: The Archaeology of Local, Regional, and International Exchange*, edited by M. M. Mango, 145-56. Society for the Promotion of Byzantine Studies 14. Surrey, United Kingdom: Ashgate.

Günsenin, N., and E. Rieth. 2012. “Un graffito de bateau a voile latine sur une amphore (IXe s. ap. J.-C.) du *Portus Theodosiacus* (Yenikapı).” *Anatolia Antiqua* XX:157-64.

Guyon, M., and E. Rieth. 2009. “The Gallo-Roman Wrecks from Lyon, Parc Saint Georges (France) — New Archaeological Data on Ancient Inland ‘Bottom-Based

Shipbuilding.'" In *Between the Seas: Transfer and Exchange in Nautical Technology*. *Proceedings of the 11th International Symposium on Boat and Ship Archaeologu (ISBSA 11)*, edited by R. Bockius, 157-66. Mainz, Germany: Verlag des Römisch-Germanischen Zentralmuseums.

Haldane, C. 1993. "Direct Evidence for Organic Cargoes in the Late Bronze Age." *World Archaeology* 24.3:348-60.

Haldon, J. 1986. "Comes Horreorum—Komēs tēs Lamias." *Byzantine and Modern Greek Studies* 10:203-10.

Haldon, J. F. 1990. *Byzantium in the Seventh Century: The Transformation of a Culture*. Cambridge, United Kingdom: Cambridge University Press.

Haldon, J. 1999a. "The Idea of the Town in the Byzantine Empire." In *The Idea and Ideal of the Town between Late Antiquity and the Early Middle Ages*, edited by G. P. Brogiolo and B. Ward-Perkins, 1-24. Leiden, Netherlands: Brill.

Haldon, J. 1999b. *Warfare, State and Society in the Byzantine World, 565-1204*. London: Routledge.

Haldon, J. 2000. "Theory and Practice in Tenth-Century Military Administration. Chapters II, 44 and 45 of the *Book of Ceremonies*." *Travaux et Memoires* 13:201-352.

Haldon, J. 2005. *The Palgrave Atlas of Byzantine History*. Houndmills, UK: Palgrave Macmillan.

Haldon, J. 2008. "Military Technology and Warfare." In *The Oxford Handbook of Byzantine Studies*, edited by E. Jeffreys, with J. Haldon and R. Cormack, 473-82. Oxford, United Kingdom: Oxford University Press.

Hamilton, D. L. 1999. Methods of Conserving Underwater Archaeological Material Culture. Conservation Files: ANTH 605, Conservation of Cultural Resources I. Nautical Archaeology Program, Texas A&M University, http://nautarch.tamu.edu/class/ANTH 605. (February 2013).

Hanson, W. S. 1978. "The Organisation of Roman Military Timber-Supply." *Britannia* 9:293-305.

Harland, J. 2006. *Seamanship in the Age of Sail*. London: Conway Maritime Press.

Harpster, M. 2005a. "A Re-assembly and Reconstruction of the 9th-Century AD Vessel Wrecked off the Coast of Bozburun, Turkey." Unpublished Ph.D. Dissertation, Texas A&M University.

Harpster, M. B. 2005b. "Dowels as a Means of Edge-to Edge Joinery in the 9th-Century AD Vessel from Bozburun, Turkey." *IJNA* 34.1:88-94.

Harpster, M. 2006. "Geometric Rules in Early Medieval Ships: Evidence from the Bozburun and Serçe Limanı Vessels." In *Connected by the Sea: Proceedings of the Tenth International Symposiun on Boat and Ship Archaeology, Roskilde 2003 (ISBSA 10)*, edited by L. Blue, F. Hocker, and A. Englebert, 95-8. Oxford, United Kingdom: Oxbow Books.

Harpster, M. 2009. "Designing the 9th-Century AD Vessel from Bozburun, Turkey." *IJNA* 38.2:297-313.

Harpster, M., and N. Coureas. 2008. “Codex Palatinus Graecus 367: A Thirteenth-Century Method of Determining Vessel Burden?” *Mariner’s Mirror* 94.1:8-20.

Harvey, A. 1989. *Economic Expansion of the Byzantine Empire 900-1200*. Cambridge, United Kingdom: Cambridge University Press.

Harvey, A. 1995. “The Middle Byzantine Economy: Growth or Stagnation?” *Byzantine and Modern Greek Studies* 19:243-61.

Hasslöf, O. 1963. “Wrecks, Archives, and Living Tradition. Topical Problems in Marine-Historical Research.” *Mariner’s Mirror* 49.3:162-77.

Hasslöf, O. 1972. “Main Principles in the Technology of Shipbuilding.” In *Ships, Shipyards, Sailors, and Fishermen. Introduction to Maritime Ethnology*, edited by O. Hasslöf, H. Henningsen, and A. E. Christiansen, 27-72. Copenhagen, Denmark: Copenhagen University Press.

Hawkins, C. W. 1977. *The Dhow: An Illustrated History of the Dhow and its World*. Lymington, Hampshire, United Kingdom: Nautical Publishing Co.

Hawkins, C. W. 1982. *Praus of Indonesia*. London: Macmillan/Nautical Books.

Hayes, J. W. 1992. *Excavations at Saraçhane in Istanbul*. Volume 2: *The Pottery*. Princeton, NJ: Princeton University Press.

Henderson, J., J. Evans, and Y. Barkoudah. 2009. “The Roots of Provenance: Glass, Plants, and Isotopes in the Islamic Middle East.” *Antiquity* 83:414-29.

Hendy, M. F. 1985. *Studies on the Byzantine Monetary Economy c. 300-1450*. Cambridge, United Kingdom: Cambridge University Press.

Hocker, F. M. 1995. “The Byzantine Shipwreck at Bozburun, Turkey. The 1995 Field Season.” *INA Quarterly* 22.4:3-9.

Hocker, F. M. 1998a. “The Byzantine Shipwreck at Bozburun, Turkey: The 1997 Field Season.” *INA Quarterly* 25.2:12-7.

Hocker, F. M. 1998b. “Bozburun Byzantine Shipwreck Excavation: The Final Campaign 1998.” *INA Quarterly* 25:4:3-13.

Hocker, F. M. 2004a. “Tools.” In *Serçe Limanı: A Eleventh-Century Shipwreck. Volume I: The Ship and Its Anchorage, Crew, and Passengers*, by G. F. Bass, S. D. Matthews, J. R. Steffy, and F. H. van Doorninck, 297-328. College Station, TX: Texas A&M University Press.

Hocker, F, M. 2004b. “Bottom-Based Shipbuilding in Northwestern Europe.” In *The Philosophy of Shipbuilding: Conceptual Approaches to the Study of Wooden Ships*, edited by F. M. Hocker and C. A. Ward, 65-94. College Station, TX: Texas A&M University Press.

Hocker, F. M., and J. M. McManamon. 2006. “Mediaeval Shipbuilding in the Mediterranean and Written Culture at Venice.” *Mediterranean Historical Review* 21.1:1-37.

Hocker, F. M., and M. Scafuri. 1996. “The Bozburun Byzantine Shipwreck Excavation: 1996 Campaign.” *INA Quarterly* 23.4:3-9.

van Holk, A. F. L. 2006. “A Roman Barge with an Artefactual Inventory from De Meern (the Netherlands).” In *Connected by the Sea: Proceedings of the Tenth International Symposium on Boat and Ship Archaeology, Roskilde 2003*, edited by L, Blue, F. Hocker, and A. Englebert, 295-99. ISBSA 10. Oxford, United Kingdom: Oxbow Books.

Horden, P. 2005. "Mediterranean Plague in the Age of Justinian." In *The Cambridge Companion to the Age of Justinian*, edited by M. Maas, 134-60. Cambridge, United Kingdom: Cambridge University Press.

Hornell, J. 1946. *Water Transport. Origins & Early Evolution*. Cambridge, United Kingdom: Cambridge University Press.

Horridge, G. A. 1979. *The Konjo Boatbuilders and the Bugis Prahus of South Sulawesi*. Maritime Monographs and Reports No. 40. Basildon, United Kingdom: Trustees of the National Maritime Museum.

Horsley, J. E. 1978. *Tools of the Maritime Trades*. Camden, ME: International Marine Publishing Company.

van der Horst, A. J. 2001. "Painting and Preserving the Ship in the 17th and 18th Centuries." IJNA 30.2:273-8.

Hourani, G. F. 1995. *Arab Seafaring in the Indian Ocean in Ancient and Medieval Times*. Princeton, NJ: Princeton University Press.

Hoving, A. J. 2012. *Nicolaes Witsen and Shipbuilding in the Dutch Golden Age*. College Station, TX: Texas A&M University Press.

Howard-Johnston, J. D. 1995. "The Siege of Constantinople in 626." In *Constantinople and Its Hinterland*, edited by C. Mango and G. Dagron, 131-42. Aldershot, United Kingdom: Variorum.

Howarth, D. 1977. *Dhows*. London: Quartet Books.

Humphrey, J. W., J. P. Oleson, and A. N. Sherwood, eds. 1998. *Greek and Roman Technology: A Sourcebook. Annotated Translations of Greek and Latin Texts and Documents*. London: Routledge.

Imber, C. 1980. "The Navy of Suleiman the Magnificent." *Archivum Ottomanicum* 6:211-82.

Inalcık, H. (with D. Quataert). 1996. *An Economic and Social History of the Ottoman Empire, 1300-1914*. Cambridge, United Kingdom: Cambridge University Press.

Ingram, R. S., and M. R. Jones. 2010. "Yenikapı: Documenting Two Byzantine Merchant Ships from the Yenikapı Excavations in Istanbul, Turkey." *INA Annual 2010*:8-17.

Ingram, R. S., and M. R. Jones. 2011. "The Yenikapı Project: Continuing Research on Two Byzantine Shipwrecks from Constantinople's Theodosian Harbor." *INA Annual 2011*:18-22.

Israeli, E., and Y. Kahanov. 2012. "Tantura E: Hull Construction Report." In *Between Continents: Proceedings of the Twelfth Symposium on Boat and Ship Archaeology, Istanbul 2009 (ISBSA 12)*, edited by N. Günsenin, 43-8. Istanbul, Turkey: Zero Prodüksiyon.

Istanbul Archaeological Museums. http://www.istanbularkeoloji.gov.tr. (March 2013).

Jacoby, D. 2000a. "Byzantine Trade with Egypt from the Mid-Tenth Century to the Fourth Crusade." *Thesaurismata* 30:25-75.

Jacoby, D. 2000b. "The Byzantine Outsider in Trade (c. 900-c. 1350)." In *Strangers to Themselves: The Byzantine Outsider*, edited by D. C. Smythe, 129-48. Society for the Promotion of Byzantine Studies Publications 8. Aldershot, United Kingdom: Ashgate.

Jacoby, D. 2004. “Silk Economics and Cross-Cultural Artistic Interaction: Byzantium, the Muslim World, and the Christian West.” *DOP* 58:197-240.

Jacoby, D. 2007. “Houses and Urban Layout in the Venetian Quarter of Constantinople: Twelfth and Thirteenth Centuries.” In *Byzantina Mediterranea: Festschrift für Johannes Koder zum 65. Geburtstag*, edited by K. Belke, E. Kislinger, A. Külzer, and M. A. Stassinopoulou, 269-82. Vienna: Böhlau Verlag.

Jacoby, D. 2008. “Silk Production.” In *The Oxford Handbook of Byzantine Studies*, edited by E. Jeffreys with J. Haldon and R. Cormack, 421-28. Oxford, United Kingdom: Oxford University Press.

Jacoby, D. 2009. “Venetian Commercial Expansion in the Eastern Mediterranean, 8th-11th Centuries.” In *Byzantine Trade, 4th-12th Centuries. The Archaeology of Local, Regional, and Interregional Trade*, edited by M. M. Mango, 371-92. Papers of the Thirty-Eighth Spring Symposium of Byzantine Studies, St. John’s College, University of Oxford, March 2004. Burlington, VT: Ashgate Publishing.

Jal, A. 1848. *Glossaire nautique*. Paris: Didot Frères.

Janin, R. 1964. *Constantinople byzantin. Développement urbain et repertoire topographique*. Paris: Institut Français d’études Byzantines.

Jewell, J. H. A. 1969. *Dhows at Mombasa*. Nairobi, Kenya: East African Publishing House.

Jézégou M.-P. 1992. “L’epave II de l’Anse Saint-Gervais a Fos-sur-Mer.” Unpublished Ph.D. dissertation, University of Provence.

Johnstone, W. 1981. “The Signs.” In *Lilybaeum*, edited by H. Frost, 191-239. Rome: Accademia nazionale dei Lincei.

Joncheray, J.-P. 1977. “Mediterranean Hull Types Compared 2. Wreck F from Cape Dramont (Var), France.” *IJNA* 6.1:3-7.

Joncheray, J.-P. 1980. “Mediterranean Hull Types Compared 4: An Unusual Type of Construction. The Hull of Wreck 1 at Bon Porté.” Translated by R. Rieu, O. Jestin, and F. Carrazé. *IJNA* 9.1:70-2.

Joncheray, J.-P. 2007a. “L’épave sarrasine (haut Moyen-Âge) de Bataiguier, ou Batéguier, opérations archéologiques de 1973 et 1974.” *CahArchSubaq* 16:131-222.

Joncheray, J.-P. 2007b. “L’épave sarrasine Agay A: campagne 1996.”*CahArchSubaq* 16:223-48.

Jones, A. H. M. 1964. *The Later Roman Empire 284-602: A Social Economic and Administrative Survey*, Vols. 1-2. Norman, OK: University of Oklahoma Press.

Jones, A. H. M. 1971. *Cities of the Eastern Roman Provinces*. London: Oxford University Press.

Kahanov, Y. 2010. “Introduction.” In *Transferts technologiques en architecture navale Méditerranéenne de l’antiquité aux temps Modernes: identité technique et identité culturelle. Actes de la Table Ronde d’Istanbul, 19-22 mai 2007*, edited by

P. Pomey, 77-86. Varia Anatolica XX. Paris: De Boccard/Institut Français D'Etudes Anatoliennes George- Dumezil.

Kahanov, Y. 2011a. "The Dor/Tantura Shipwrecks: Clues to Their Construction Tradition." *Archaeologia Maritima Mediterranea* 8:137-52.

Kahanov, Y. 2011b. "Ship Reconstruction, Documentation, and Recording." In *The Oxford Handbook of Maritime Archaeology*, edited by A. Catsambis, D. L. Hamilton, and B. Ford, 161-81. Oxford, United Kingdom: Oxford University Press.

Kahanov, Y., and H, Mor. 2006. "The Dor 2001/1 wreck, Dor/Tantura Lagoon, Israel: Preliminary Report." In *Connected by the Sea: Proceedings of the Tenth International Symposiun on Boat and Ship Archaeology, Roskilde 2003 (ISBSA 10)*, edited by L. Blue, F. Hocker, and A. Englebert, 84-8. Oxford, United Kingdom: Oxbow Books.

Kahanov, Y., and H. Mor. 2009. "Dor 2001/1: Updated Information and the Retrieval of a Section of the Shipwreck." In *Between the Seas: Transfer and Exchange in Nautical Technology: Proceedings of the Eleventh International Symposium on Boat and Ship Archaeology, Mainz 2006, ISBSA 11*, edited by R. Bockius, 17-24. Mainz, Germany: Römisches-Germanisches Zentralmuseum.

Kahanov. Y., and J. G. Royal. 1996. "The 1995 INA/CMS Tantura A Byzantine Shipwreck Excavation- Hull Construction Report." *CMS News Report* 3: 21-3.

Kahanov, Y., and J. G. Royal. 2001. "Analysis of Hull Remains of the Dor D Vessel, Tantura, Israel." *IJNA* 30.2:257-65.

Kahanov, Y. and E. Linder. 2004. *The Ma'agan Mikhael Ship. The Recovery of a 2400-Year-Old Merchantman.* Volume II: *Final Report*. Jerusalem, Israel: Israel Exploration Society and the University of Haifa.

Kahanov, Y., J. Royal, and J. Hall. 2004. "The Tantura Wrecks and Ancient Mediterranean Shipbuilding." In *The Philosophy of Shipbuilding. Conceptual Approaches to the Study of Wooden Ships*, edited by F. M. Hocker and C. A. Ward, 113-29. College Station, TX: Texas A & M University Press.

Karagöz, Ş. 2007. "The Role of Chrysopolis in History as a Colony City." In *Istanbul: 8,000 Years Brought to Daylight: Marmaray, Metro, Sultanahmet Excavations*, edited by Z. Kızıltan, 34-53. Istanbul, Turkey: Vehbi Koç Vakfı.

Katzev, M. L. 1982. "Iron Objects." In *Yassi Ada: A Seventh-Century Byzantine Shipwreck*, by G. F. Bass and F. H. van Doorninck, 231-65. College Station, TX: Texas A & M University Press.

Kavanagh, B. F. 2006. *Surveying: Principles and Applications*. Upper Saddle River, NJ: Pearson/Prentice Hall.

Kazhdan, A. P. 1991 (ed.). *The Oxford Dictionary of Byzantium*, vols. 1-3. New York: Oxford University Press.

Kazhdan, A. P., and G. Constable. 1982. *People and Power in Byzantium*. Washington DC: Dumbarton Oaks.

Khalilieh, H. S. 2005. "The Enigma of Tantura B: Historical Documentation and the Lack of Circumstantial Documentary Evidence." *IJNA* 34.2:314-22.

Kızıltan, Z. 2007. “Marmaray Project and 8000 Years of Istanbul “Brought to Daylight.” In *Istanbul: 8,000 Years Brought to Daylight: Marmaray, Metro, Sultanahmet Excavations*, edited by Z. Kızıltan, 18-21. Istanbul, Turkey: Vehbi Koç Vakfı.

Kızıltan, Z. 2010. “Excavations at Yenikapı, Sirkecı, and Üsküdar within Marmaray and Metro Projects.” In *Istanbul Archaeological Museums Proceedings of the 1st Symposium on Marmaray-Metro Salvage Excavations, 5th-6th May 2008,* edited by U. Kocabaş, 1-16. Istanbul, Turkey: Istanbul Archaeological Museums/Epsilon.

Kocabaş, U., ed. 2008. *The ‘Old Ships’ of the ‘New Gate*.’ Istanbul, Turkey: Zero Prod. Ltd.

Kocabaş, U. 2012a. “Byzantine Shipwrecks at Yenikapı.” In *Between Continents: Proceedings of the Twelfth Symposium on Boat and Ship Archaeology, Istanbul 2009 (ISBSA 12),* edited by N. Günsenin, 107-14. Istanbul, Turkey: Zero Prodüksiyon.

Kocabaş, U. 2012b. “The Latest Link in the Long Tradition of Maritime Archaeology in Turkey: The Yenikapı Shipwrecks.” *EJA* 15.2: 309-23.

Kocabaş, U., and I. Özsait-Kocabaş. 2007. “Istanbul University Construction Techniques and Features of the Shipwrecks in the Yenikapı Byzantine Shipwrecks Project.” In *Istanbul Archaeological Museums Proceedings of the 1st Symposium on Marmaray-Metro Salvage Excavations, 5th-6th May 2008*, edited by U. Kocabaş, 196-201. Istanbul, Turkey: Istanbul Archaeological Museums/Epsilon.

Kocabaş, U., and I. Özsait-Kocabaş. 2010. “Shipwrecks at the Theodosian Harbor.” In *Transferts technologiques en architecture navale Méditerranéenne de l’antiquité aux temps Modernes: identité technique et identité culturelle. Actes de la Table Ronde d’Istanbul, 19-22 mai 2007*, edited by P. Pomey, 109-30. Varia Anatolica XX. Paris: De Boccard/Institut Français D’Etudes Anatoliennes George-Dumezil.

Koder, J. 1995. “Fresh Vegetables for the Capital.” In *Constantinople and its Hinterland*, edited by C. Mango and G. Dagron, 49-56. Aldershot, United Kingdom: Ashgate Publishing Ltd.

Koder, J. 2002. “Maritime Trade and the Food Supply for Constantinople in the Middle Ages.” In *Travel in the Byzantine World*, edited by R. Macrides, p. 109-24. Society for the Promotion of Byzantine Studies Publications 10. Aldershot, United Kingdom: Ashgate Publishing Limited.

Koder, J. 2007. “*Stew and salted meat*—opulent normality in the diet of every day?” In *Eat, Drink, and Be Merry (Luke 12:19): Food and Wine in Byzantium; Papers of the 37th Annual Spring Symposium of Byzantine Studies, in Honour of Professor A. ed by A. M. Bryer*, edited by L. Brubaker and K. Linardou, 59-74. Burlington, VT: Ashgate.

Koutrakou, N. 1995. “Diplomacy and Espionage: Their Role in Byzantine Foreign Relations, 8th-10th Centuries.” *Graeco-Arabica* 6.6:125-44.

Kreutz, B. M. 1976. “Ships, Shipping, and the Implications of Change in the Early Medieval Period.” *Viator* 7:79-109.

Kreutz, B. M. 1988. “The Ecology of Maritime Success: the Puzzling Case of Amalfi.” *Mediterranean Historical Review* 3:103-13.

Kreutz, B. M. 1994. “Ghost Ships and Phantom Cargoes: Reconstructing Early Amalfitan Trade.” *Journal of Medieval History* 20:347-57.

Kuniholm, P. I., C. B. Griggs, and M. W. Newton. 2007. “Evidence for Early Timber Trade.” In *Byzantina Mediterranea. Festschrift für Johannes Koder zum 65. Geburtstag*, edited by K. Belke, E. Kislinger, A. Külzer, and M. A. Stassinopoulou, 365-85. Vienna: Böhlau.

Laiou, A. E. 1993. “Byzantine Traders and Seafarers.” In *The Greeks and the Sea*, edited by S. Vryonis, 79-96. New Rochelle, NY: Aristide D. Caratzas, Publisher.

Laiou, A. E. 2002a. “Political History: An Outline.” In *The Economic History of Byzantium from the Seventh Through the Fifteenth Century*, edited by A. E. Laiou, 9-28. Dumbarton Oaks Series No. 39. Washington, DC: Dumbarton Oaks.

Laiou, A. E. 2002b. “The Human Resources.” In *The Economic History of Byzantium from the Seventh Through the Fifteenth Century*, edited by A. E. Laiou, 47-55. Dumbarton Oaks Series No. 39. Washington, DC: Dumbarton Oaks.

Laiou, A. E. 2002c. “Economic and Noneconomic Exchange.” In *The Economic History of Byzantium from the Seventh Through the Fifteenth Century*, edited by A. E. Laiou, 681-96. Dumbarton Oaks Series No. 39. Washington, DC: Dumbarton Oaks.

Laiou, A. E. 2002d. “Exchange and Trade, Seventh-Twelfth Centuries.” In *The Economic History of Byzantium from the Seventh Through the Fifteenth Century*, edited by A. E. Laiou, 697-770. Dumbarton Oaks Series No. 39. Washington, DC: Dumbarton Oaks.

Laiou, A. E. 2002e. "The Byzantine Economy: An Overview." In *The Economic History of Byzantium from the Seventh Through the Fifteenth Century*, edited by A. E. Laiou, 1145-164. Dumbarton Oaks Series No. 39. Washington, DC: Dumbarton Oaks.

Laiou, A. E., and C. Morrisson. 2007. *The Byzantine Economy*. Cambridge, United Kingdom: Cambridge University Press.

Lane, F. C. 1964. "Tonnages, Medieval and Modern." *Economic History Review* 17.2:213-33.

Lawrence, A. W. 1983. "A Skeletal History of Byzantine Fortification." *BSA* 78: 171-227.

Le Baron Bowen, R. 1949. "Arab Dhows of Eastern Arabia." *American Neptune* 9:87-132.

Le Baron Bowen, R. 1953. "Eastern Sail Affinities." *American Neptune* 13:187-98.

Lemée, C. P. P. 2006. *The Renaissance Shipwrecks from Christianshaven*. Ships and Boats of the North Volume 6. Roskilde, Denmark: Viking Ship Museum.

Lever, D. 1998. *The Young Sea-Officer's Sheet Anchor, Or a Key to the Leading of Rigging and to Practical Seamanship*. Reprint of the 1819 edition, published by John Richardson, London. Mineola, NY: Dover Publications.

Linder, E. and Y. Kahanov. 2003. *The Ma'agan Mikhael Ship: The Recovery of a 2400-Year-Old Merchantman.* Volume 1: *Final Report*. Jerusalem, Israel: Israel Exploration Society and the University of Haifa.

Liou, B. 1974. "L'épave romaine de l'anse Gerbal (Port-Vendres)." *CRAI* 118.3:414-33.

Liphschitz, N. and C. Pulak. 2007/2008. "Wood Species Used in Ancient Shipbuilding in Turkey: Evidence from Dendroarchaeological Studies." *Skyllis* 1.2:73-82.

Liphschitz, N., and C. Pulak. 2009. "Shipwrecks of the Portus Theodosiacus. Types of Wood Used in Some Byzantine Roundships and Longships found at Yenikapı, Istanbul." *Skyllis* 9.2:164-71.

Lishman, N. 1961. "Arab Lateeners." *Mariner's Mirror* 47.1:57.

Loewen, B. 2005. "Resinous Paying Materials in the French Atlantic, AD 1500-1800. History, Technology, Substances." *IJNA* 34.2:238-52.

Loewen, B. 2007. "Archaeology of a 16th-Century Basque Whaling Ship: Concepts and Questions." In *The Underwater Archaeology of Red Bay. Basque Shipbuilding and Whaling in the 16th Century*. Volume III: *The 24M Hull*, edited by R. Grenier, M. André Bernier, and W. Stevens, 1-24. Ottowa, Canada: Parks Canada.

Long, L., S. Marlier, and M. Rival. 2009. "The Saintes-Marie-de-la-Mer 24 (SM 24) Shipwreck (France, A.D. 40-75): a Sea-River Cargo Vessel with Stitched Frames." In *Between the Seas: Transfer and Exchange in Nautical Technology. Proceedings of the 11th International Symposium on Boat and Ship Archaeologu*

(ISBSA 11), edited by R. Bockius, 277-88. Mainz, Germany: Verlag des Römisch-Germanischen Zentralmuseums.

Long, P. O., D. McGee, and A. M. Stahl (eds.). 2009. *The Book of Michael of Rhodes: A Fifteenth Century Maritime Manuscript*. Vols. 1-3. Cambridge, MA: MIT Press.

Lopez, R. S. 1945. "Silk Industry in the Byzantine Empire." *Speculum* 20.1:1-42.

Lopez, R. S. 1959. "The Role of Trade in the Economic Readjustment of Byzantium in the Seventh Century." *DOP* 13:67-85.

Louth, A. 2008. "Byzantium Transforming (600-700)." In *The Cambridge History of the Byzantine Empire, c. 500-1492*, edited by J. Shepard, 221-48. Cambridge, United Kingdom: Cambridge University Press.

Lucas, A., and J. R. Harris. 1999. *Ancient Egyptian Materials and Industries*. Reprint: Mineolo, NY: Dover Publications, Inc. Original Edition: 1962: London, Edward Arnold Publishers, Ltd.

Magdalino, P. 1995. "The Grain Supply of Constantinople, Ninth-Twelfth Centuries." In *Constantinople and its Hinterland*, edited by C. Mango and G. Dagron, 35-47. Aldershot, United Kingdom: Ashgate Publishing, Ltd.

Magdalino, P. 1998. "The Road to Baghdad in the Thought-World of Ninth-Century Byzantium." In *Studies on the History and Topography of Byzantine Constantinople*, edited by L. Brubaker, 195-214. Society for the Promotion of Byzantine Studies Publications 5. Aldershot, United Kingdom: Variorum.

Magdalino, P. 2000. "The Maritime Neighborhoods of Constantinople: Commercial and Residential Functions, Sixth to Twelfth Centuries." *DOP* 54:209-26.

Magdalino, P. 2001. “Aristocratic *oikoi* in the Tenth and Eleventh Regions of Constantinople.” In *Studies on the History and Topography of Constantinople*, 53-69. Aldershot, United Kingdom: Ashgate/Variorum Reprints.

Magdalino, P. 2002. “Medieval Constantinople: Built Environment and Urban Development.” In *The Economic History of Byzantium from the Seventh to the Fifteenth Century*, edited by A. E. Laiou, 529-37. Dumbarton Oaks Studies 39. Washington, DC: Dumbarton Oaks Research Library and Collection.

Magdalino 2007a. “Medieval Constantinople.” In *Studies on the History and Topography of Constantinople*, 1-111. Aldershot, United Kingdom: Ashgate/Variorum Reprints.

Magdalino, P. 2007b. “Constantine V and the Middle Age of Constantinople.” In *Studies on the History and Topography of Byzantine Constantinople*, 1-24. Aldershot, United Kingdom: Ashgate/Variorum.

Magdalino, P. 2010. “Byzantium = Constantinople.” In *A Companion to Byzantium*, edited by L. James, 43-54. Malden, MA: Wiley-Blackwell.

Makris, G. 2002. “Ships.” In *The Economic History of Byzantium from the Seventh through the Fifteenth Century*, edited by A. E. Laiou, 91-100. Dumbarton Oaks Studies 39. Washington, DC: Dumbarton Oaks Research Library and Collection.

Mango, C. 1985. *Le développement urbain de Constantinople (IVe-VIIe siècles)*. Travaux et Memoires du Centre de Recherche D’Histoire et Civilisation de Byzance Collège de France Monographies 2. Paris: Diffusion de Boccard.

Mango, C. 1993. “The Development of Constantinople as an Urban Center.” In *Studies on Constantinople*, 117-36. Aldershot, United Kingdom: Ashgate/Variorum Reprints.

Mango, C. 1995. “The Water Supply of Constantinople.” In *Constantinople and Its Hinterland*, edited by C. Mango and G. Dagron, 9-18. Society for the Promotion of Byzantine Studies Publications 3. Aldershot, United Kingdom: Variorum.

Mango, C. 2001. “The Shoreline of Constantinople in the Fourth Century.” In *Byzantine Constantinople: Monuments, Topography, and Everyday Life*, edited by N. Necipoğlu, 17-28. Leiden, Netherlands: Brill.

Mango, C., ed. 2002. *The Oxford History of Byzantium*. Oxford: Oxford University Press.

Mango, C. 2005. *Byzantium: Empire of the New Rome*. London: Phoenix Press.

Mango, M. M. 2000. “The Commercial Map of Constantinople.” *DOP* 54: 189-207.

Maniatis, G. C. 1999. “Organization, Market Structure, and Modus Operandi of the Private Silk Industry in Tenth-Century Byzantium.” *DOP* 53:263-332.

Maniatis, G. C. 2000. “The Organizational Setup and Functioning of the Fish Market in Tenth-Century Constantinople.” *DOP* 54:13-42.

Maniatis, G. C. 2001. “The Domain of Private Guilds in the Byzantine Economy, Tenth to Fifteenth Centuries.” *DOP* 55: 339-69.

Manners, I. R. 1997. “Constructing the Image of a City: The Representation of Constantinople in Christopher Buondelmonti’s *Liber Insularum Archipelagi*.” *Annals of the Association of American Geographers* 87.1:72-102.

Manning, W. H. 1985. *Catalogue of the Romano-British Iron Tools, Fittings, and Weapons in the British Museum*. London: British Museum Publications, Ltd.

Marquardt, K. H. 1992. *Eighteenth-Century Rigs and Rigging*. Cedarburg, WI: Phoenix Publications.

Marsden, P. 1976. "A Boat of the Roman Period Found at Bruges, Belgium, in 1899, and Related Types." *IJNA* 5.1:23-55.

Marsden, P. 1994. *Ships of the Port of London: First to Eleventh Centuries AD*. English Heritage Archaeological Report 3. London: English Heritage.

Martin, L. R. 2001. *The Art and Archaeology of Venetian Boats and Ships*. College Station, TX: Texas A&M University Press.

Matschke, K.-P. 2002. "Mining." In *The Economic History of Byzantium from the Seventh Through the Fifteenth Century*, edited by A. E. Laiou, 115-20. Dumbarton Oaks Series No. 39. Washington, DC: Dumbarton Oaks.

McCarthy, M. 2005. *Ships' Fastenings: From Sewn Boat to Steamship*. College Station, TX: Texas A&M University Press.

McCormick, M. 2003. "Rats, Communications, and Plague: Towards an Ecological History." *Journal of Interdisciplinary History* 34.1:1-25.

McCormick, M. 2005. *Origins of the European Economy: Communications and Commerce, A.D. 300-900*. New York: Cambridge University Press.

McCormick, M. 2012. "Movements and Markets in the First Millennium: Information, Containers, and Shipwrecks." In *Trade and Markets in Byzantium*, edited by C.

Morrisson, 51-98. Washington, DC: Dumbarton Oaks Research Library and Collection.

McGee, D. 2009. “The Shipbuilding Text of Michael of Rhodes.” In *The Book of Michael of Rhodes: A Fifteenth Century Maritime Manuscript*. Volume 3: Studies, edited by P. O. Long, 211-33. Cambridge, MA: MIT Press.

McGrail, S. 1997. “Early Frame-First Methods of Building Wooden Boats and Ships.” *Mariner’s Mirror* 83.4:76-80.

McGrail, S. 2008. “Sea Transport, Part 1: Ships and Navigation.” In *The Oxford Handbook of Engineering and Technology in the Classical World*, edited by J. P. Oleson, 606-37. Oxford, United Kingdom: Oxford University Press.

Meiggs, R. 1998. *Trees and Timber in the Ancient Mediterranean World*. Oxford, United Kingdom: Oxford at the Clarendon Press.

van Millingen, A. 1899. *Byzantine Constantinople. The Walls of the City and Adjoining Historical Sites*. London: John Murray.

Monks, G. R. 1953. “The Church of Alexandria and the City’s Economic Life in the Sixth Century.” *Speculum* 28.2:349-62.

Mor, H. 2003. “The Carpenter’s Tool-Marks: Their Significance in Ancient Boatbuilding.” In *The Ma’agan Mikhael Ship: The Recovery of a 2,400-Year-Old Merchantman*, edited by E. Black, Volume 2, 165-81. Haifa, Israel: Israel Exploration Society

Mor, H. 2010. “The Dor 2001/1 Shipwreck: Hull Construction Report.” In *Transferts technologiques en architecture navale Méditerranéenne de l’antiquité aux temps*

Modernes: identité technique et identité culturelle. Actes de la Table Ronde d'Istanbul, 19-22 mai 2007, edited by P. Pomey, 87-95. Varia Anatolica XX. Paris: De Boccard/Institut Français D'Etudes Anatoliennes George- Dumezil.

Mor, H. 2012. "The Socio-Economic Implications for Ship Construction: Evidence from Underwater Archaeology and the Codex Theodosianus." In *Shipping, Trade, and Crusade in the Medieval Mediterranean: Studies in Honor of John Pryor*, edited by R. Gertwagen and E. Jeffreys, 39-64. Burlington, VT: Ashgate.

Mor, H., and Y. Kahanov. 2006. "The Dor 2001/1 Shipwreck, Israel—a Summary of the Excavation." *IJNA* 35.2:274-89.

Morrisson, C. 2002. "Byzantine Money: Its Production and Circulation." In *The Economic History of Byzantium from the Seventh through the Fifteenth Century*, edited by A. E. Laiou, 171-220. Dumbarton Oaks Series No. 39, 909-66. Washington, DC: Dumbarton Oaks.

Morrisson, C., and J.-P. Sodini. 2002. "The Sixth-Century Economy." In *The Economic History of Byzantium from the Seventh through the Fifteenth Century*, edited by A. E. Laiou, 171-220. Dumbarton Oaks Series No. 39, 171-220. Washington, DC: Dumbarton Oaks.

Mott, L. V. 1997. *The Development of the Rudder: A Technological Tale*. College Station, TX: Texas A&M University Press.

Muller, S. D. 2004. "Palynological Study of Antique Shipwrecks From the Western Mediterranean Sea, France." *JAS* 31:345-49.

Müller-Wiener, W. 1977. *Bildlexicon zur Topographie Istanbuls*. Tübingen, Germany: Verlag Ernst Wasmuth.

Müller-Wiener, W. 1994. *Die Häfen von Byzantion Konstantinupolis Istanbul.* Tübingen, Germany: Ernst Wasmuth Verlag.

Murphey, R. 1988. "Provisioning Istanbul: The State and Subsistence in the Early Modern Middle East." *Food and Foodways* 2: 217-63.

Murray, W. M. 1987. "Do Modern Winds Equal Ancient Winds?" *Mediterranean Historical Review* 22:139-67.

Muthesius, A. 1993. "The Byzantine Silk Industry: Lopez and Beyond." *Journal of Medieval History* 19:1-67.

Muthesius, A, 2002. "Essential Processes, Looms, and Technical Aspects of the Production of Silk Textiles." In *The Economic History of Byzantium from the Seventh Through the Fifteenth Century*, edited by A. E. Laiou, 147-68. Dumbarton Oaks Series No. 39. Washington, DC: Dumbarton Oaks.

Myrhøj, H. M. 2004. "The Planking Clamp from Tårnby: a Medieval Danish Boatbuilding Tool." *IJNA* 33.2:320-29.

Navri, R. 2011. "The Dor 2006 Shipwreck." *Skyllis* 11.1: 57-9

Nayling, N., and T. Jones. 2012. "Three-Dimensional Recording and Hull Form Modeling of the Newport (Wales) Medieval Ship." In *Between Continents: Proceedings of the Twelfth Symposium on Boat and Ship Archaeology, Istanbul 2009 (ISBSA 12)*, edited by N. Günsenin, 319-24. Istanbul, Turkey: Zero Prodüksiyon.

Nayling, N., and S. McGrail. 2004. *The Barland's Farm Romano-Celtic Boat*. CBA Research Reports 138. York, United Kingdom: Council for British Archaeology.

Nicol, D. M. 1988. *Byzantium and Venice: A Study in Diplomatic and Cultural Relations*. Cambridge, United Kingdom: Cambridge University Press.

Nieto, X., and M. Santos. 2010. "El barco griego arcaico de Cala Sant Vicenç." In *Transferts technologiques en architecture navale Méditerranéenne de l'antiquité aux temps Modernes: identité technique et identité culturelle. Actes de la Table Ronde d'Istanbul, 19-22 mai 2007*, edited by P. Pomey, 45-58. Varia Anatolica XX. Paris: De Boccard/Institut Français D'Etudes Anatoliennes George-Dumezil.

Oikonomides, N. 1986. "Silk Trade and Production from the Sixth to the Ninth Century: The Seals of *Kommerkiarioi*." *DOP* 40:33-53.

Oikonomides, N. 1995. "The Economic Region of Constantinople: From Directed Economy to Free Economy, and the Role of the Italians." In *Europa medievale e mondo bizantino*, edited by G. Arnaldi and G. Cavallo, 221-38. Rome: Istituto italiano per il medioevo.

Oikonomides, N. 2001. "The *Kommerkiarios* of Constantinople." In *Byzantine Constantinople: Monuments, Topography, and Everyday Life*, edited by N. Necipoğlu, 235-44. Leiden, Netherlands: Brill.

Oikonomides, N. 2002. "The Role of the Byzantine State in the Economy." In *The Economic History of Byzantium from the Seventh Through the Fifteenth Century*, edited by A. E. Laiou, 973-1058. Dumbarton Oaks Series No. 39. Washington, DC: Dumbarton Oaks.

Omont, H. 1929. *Miniatures des plus anciens manuscrist grecs de la Bibliothèque Nationale du VIe au XIVe siècle*. Paris: Librairie Ancienne Honoré Champion.

Onar, V., G. Pazvant, A. Armutak, H. Alpak, I. Karamut, and M. Gökçay. 2010. "Preliminary Report on the Animal Remains Uncovered from the Yenikapı Metro and Marmaray Excavations." In *Istanbul Archaeological Museums Proceedings of the 1st Symposium on Marmaray-Metro Salvage Excavations, 5th-6th May 2008*, edited by U. Kocabaş, 223-31. Istanbul, Turkey: Istanbul Archaeological Museums/Epsilon.

Oron, A., G. Hadas, N. Liphschitz, and G. Bonani. 2008. "A New Type of Composite Anchor Dated to the Fatimid-Crusader Period from the Dead Sea, Israel." *IJNA* 37.1:1-7.

Ostrogorsky, G. 2007. *History of the Byzantine State*. New Brunswick, NJ: Rutgers University Press.

Özmen, H. İ. 2007. "A Tribute to History and Culture: 'Marmaray'." In *Istanbul: 8,000 Years Brought to Daylight: Marmaray, Metro, Sultanahmet Excavations*, edited by Z. Kızıltan, 22-9. Istanbul, Turkey: Vehbi Koç Vakfı.

Özsait-Kocabaş, I. and Kocabaş, U. 2008. "Technological and Constructional Features of Yenikapı Shipwrecks: A Preliminary Evaluation." In *The 'Old Ships' of the 'New Gate*,' edited by U. Kocabaş, 97-186. Istanbul, Turkey: Zero Prod. Ltd.

Özsait-Kocabaş, I. 2012. “Hull Characteristics of the Yenikapı 12 Shipwreck.” In *Between Continents: Proceedings of the Twelfth Symposium on Boat and Ship Archaeology, Istanbul 2009 (ISBSA 12)*, edited by N. Günsenin, 115-20. Istanbul, Turkey: Zero Prodüksiyon.

Palou, H., E. Rieth, M. Izaguirre, A. Jover, X. Nieto, M. Pujol, X. Raurich, and C. Apestegui. 1998. *Excavacions arqueològiques subaquàtiques a Cala Culip*. Volume 2: *Culip VI*. Girona: Centre d’Arqueologia Subaquàtica de Catalunya.

Parker, A. J. 1992. *Ancient Shipwrecks of the Mediterranean & the Roman Provinces*. BAR-IS 580. Oxford, United Kingdom: Hadrian Books.

Parshina, E. A. 2001. “Stamped Byzantine Amphoras of the Xth Century A.D. from Laspi.” In Sea Trade in the North Black Sea Region, edited by M. I. Gladikh, 104-17. Kiev, Ukraine: National Taras Shevchenko University Press.

Perinçek, D. 2010. “Geoarchaeology of the Excavation Site for the Last 8,000 Years and Traces of Natural Catastrophes in the Geologic Profile.” In *Istanbul Archaeological Museums Proceedings of the 1st Symposium on Marmaray-Metro Salvage Excavations, 5th-6th May 2008*, edited by U. Kocabaş, 191-218. Istanbul, Turkey: Istanbul Archaeological Museums/Epsilon.

Petrie, W. M. F. 1917. *Tools and Weapons*. London: British School of Archaeology in Egypt.

Piperno, D. P. 1988. *Phytolith Analysis. An Archaeological and Geological Perspective*. San Diego, CA: Academic Press, Inc.

Pitarakis, B. 2012. “Daily Life in the Marketplace in Late Antiquity and Byzantium.” In *Trade and Markets in Byzantium*, edited by C. Morrisson, 399-428. Washington, DC: Dumbarton Oaks Research Library and Collection.

Polunin, O. 1976. *Trees and Bushes of Europe*. London: Oxford University Press.

Polzer, M. 2008. “Toggles and Sails in the Ancient World: Rigging Elements Recovered from the Tantura B Shipwreck, Israel.” *IJNA* 37.2:225-52.

Polzer, M. 2010. “The VIth-Century B.C. Shipwreck at Pabuç Burnu, Turkey. Evidence for Transition from Lacing to Mortise-and-Tenon Joinery in Late Archaic Greek Shipbuilding.” In *Transferts technologiques en architecture navale Méditerranéenne de l’antiquité aux temps Modernes: identité technique et identité culturelle. Actes de la Table Ronde d’Istanbul, 19-22 mai 2007,* edited by P. Pomey, 27-44. Varia Anatolica XX. Paris: De Boccard/Institut Français D’Etudes Anatoliennes George- Dumezil.

Pomey, P. 1981. “L’épave de Bon-Porté et les bateaux cousus de Méditerranée.” *Mariner’s Mirror* 67.3:225-44.

Pomey, P. 2001. “Les épaves grecques archaïques du VIe siècle av. J.-C. de Marseille: épaves Jules-Verne 7 et 9 et César 1.” In *Tropis VI: Proceedings of the 6th International Symposium on Ship Construction in Antiquity, Lamia, 28, 29, 30 August 1996*, edited by H. Tzalas, 425-37. Athens, Greece: Hellenic Institute for the Preservation of Nautical Tradition.

Pomey, P. 2004. “Principles and Methods of Construction in Ancient Naval Architecture.” In *The Philosophy of Shipbuilding: Conceptual Approaches to the*

Study of Wooden Ships, edited by F. M. Hocker and C. A. Ward, 25-36. College Station, TX: Texas A&M University Press.

Pomey, P. 2006. "The Kelenderis Ship: A Lateen Sail." *IJNA* 35.2:326-35.

Pomey, P., and A. Tchernia. 1978. "Le tonnage maximum des navires de commerce romains." *Archaeonautica* 2:233-52.

Pomey, P., Y. Kahanov, and E. Rieth. 2012. "Transition from Shell to Skeleton in Ancient Mediterranean Ship-Construction: Analysis, Problems, and Future Research." *IJNA* 41.2:235-314.

Poveda, P. 2012. "Hypothetical Reconstruction of the *Dramont E* Shipwreck." In *Between Continents: Proceedings of the Twelfth Symposium on Boat and Ship Archaeology, Istanbul 2009 (ISBSA 12)*, edited by N. Günsenin, 331-36. Istanbul, Turkey: Zero Prodüksiyon.

Pryor, J. H. 1984. "The Naval Architecture of Crusader Transport Ships: A Reconstruction of Some Archetypes for Round-Hulled Sailing Ships: Part II." *Mariner's Mirror* 70, 275-92.

Pryor, J. H. 1994. "The Mediterranean Round Ship." In *Cogs, Caravels, and Galleons: The Sailing Ship 1000-1650*, edited by R. Gardiner, 59-76. London: Conway Maritime Press.

Pryor, J. H. 1995. "From *Dromon* to *Galea*: Mediterranean Bireme Galleys AD 500-1300." In *The Age of the Galley*, edited by R. Gardiner, 101-16. Greenwich, United Kingdom: Conway Maritime Press.

Pryor, J. H. 2000. *Geography, Technology, and War: Studies in the Maritime History of the Mediterranean, 649-1571*. New York: Cambridge University Press.

Pryor, J. H. 2002. "Types of Ships and their Performance Capabilities." In *Travel in the Byzantine World*, edited by R. Macrides, 33-58. Society for the Promotion of Byzantine Studies Publications 10. Aldershot, United Kingdom: Ashgate Publishing Ltd.

Pryor, J. H. 2008. "Shipping and Seafaring." In *The Oxford Handbook of Byzantine Studies*, edited by E. Jeffreys, with J. Haldon and R. Cormack, 482-91. Oxford, United Kingdom: Oxford University Press.

Pryor, J. H., and E. M. Jeffreys. 2006. *Age of the ΔΡΟΜΩΝ: The Byzantine Navy ca 500-1204*. Leiden, Netherlands: Brill.

Pulak, C. 1999. "A Late Bronze Age Shipwreck at Uluburun. Aspects of Hull Construction." In *The Point Iria Wreck: Interconnections in the Mediterranean, ca. 1200 BC*, edited by W. Phelps, Y. Lolos, and Y. Vichos, 209-38. Athens, Greece: Hellenic Institute of Marine Archaeology (HIMA).

Pulak, C. 2000. "The Copper and Tin Ingots from the Late Bronze Age Shipwreck at Uluburun." *Der Anschnitt* 13:137-57.

Pulak, C. 2003. "Mortise-and-Tenon Joints of Bronze Age Seagoing Ships." In *Boats, Ships, and Shipyards. Proceedings of the Ninth International Symposium on Boat and Ship Archaeology, Venice 2000 (ISBSA 9)*, edited by C. Beltrame, 28-34. Oxford, United Kingdom: Oxbow Books.

Pulak, C. 2007a. "Yenikapı Byzantine Shipwrecks." In *Istanbul: 8,000 Years Brought to Daylight: Marmaray, Metro, Sultanahmet Excavations*, edited by Z. Kızıltan, 202-15. Istanbul, Turkey: Vehbi Koç Vakfı.

Pulak, C. 2007b. "Yenikapı Batıkları: Fırtınanın Armağanı." *Arkeoatlas 2007*:129-41.

Pulak, C. 2007c. "Yenikapı Batikları." *Atlas* 172:100-15.

Pulak, C. 2007d. *Yenikapı Buluntularının Teknoloji Tarihine Katkısı*. Istanbul, Turkey: TTMOB Mimarlar Odası Büyükkent Şubesi.

Pulak, C., R. Ingram, M. Jones, and S. Matthews. 2013. "The Shipwrecks of Yenikapı and Their Contribution to the Study of Ship Construction." In *Stories from the Hidden Harbor: Shipwrecks of Yenikapı*, edited by Z. Kızıltan and G. Baran Çelik, 23-34. Istanbul, Turkey: Istanbul Archaeological Museums Press.

Rackham, O. 1982. "The Growing and Transport of Timber and Underwood." In Woodworking Techniques Before 1500, edited by S. McGrail, 199-218. National Maritime Museum, Greenwich, Archaeological Series No. 7. BAR-IS 129. Oxford, United Kingdom: British Archaeological Reports.

Ravn, M. 2012. "Recent Advances in Post-Excavation Documentation: Roskilde Method." In *Between Continents: Proceedings of the Twelfth Symposium on Boat and Ship Archaeology, Istanbul 2009 (ISBSA 12),* edited by N. Günsenin, 313-18. Istanbul, Turkey: Zero Prodüksiyon.

Reinert, S. W. 1998. "The Muslim Presence in Constantinople, 9th-15th Centuries: Some Preliminary Observations." In *Studies on the Internal Diaspora of the Byzantine*

Empire, edited by H. Ahrweiler and A. E. Laiou, 125-150. Washington DC: Harvard University Press.

Riccardi, E. 2002. "A ship's mast discovered during excavation of the Roman port at Olbia, Sardinia." *IJNA* 31.2:268-69.

Rickman, G. E. 1980. *The Corn Supply of Ancient Rome*. Oxford, United Kingdom: Clarendon Press.

Rieth, E. 1998. *Des bateaux et des fleuves*. Paris: Editions Errance.

Rieth, E. 2003. "First Archaeological Evidence of a Mediterranean Whole Moulding Ship Design Method: The Example of the Culip VI Wreck, Spain (XIIIth-XIVth c.)." In *Shipbuilding Practice and Ship Design Methods from the Renaissance to the 18th Century*, edited by H. Nowacki and M. Valleriani, 9-16. Max Planck-Institute for the History of Science Preprint No. 245. www.mpiwg-berlin.mpg.de/Preprints/P245.PDF.

Rieth, E. 2008. "Géométrie des formes de carene et construction «sur membrure première» (Ve-XIIe siècles). Une autre approche de l'histoire de l'architecture navale Méditerranéenne au Moyen Age?" *Archaeologia Maritima Mediterranea* 5:45-68.

Rieth, E., C. Carrierre-Desbois, and Virginie Serna. 2001. *L'épave de Port Berteau II (Charente-Maritime). Un caboteur fluvio-maritime du haut Moyen Âge et son contexte nautique*. Paris: Éditions de la Maison des sciences de l'Homme.

Rival, M. 1991. *La charpenterie navale romaine*. Paris: Editions du Centre National de la Recherche Scientifique.

Roberts, O. T. P. 2006. “The Rig of the Kelenderis Ship Reconsidered.” *IJNA* 35.2:330-31.

Romano, B. C. 1607. *Nautica mediterranea*. Rome: Tolomeo Bonfadino.

Rosen, B., E. Galili, and M. Weinstein-Evron. 2009. “Thorny Burnet (*Sarcopoterium spinosum* L.) in a Roman Shipwreck off the Israeli Coast and the Role of Non-Timber Shrubs in Ancient Mediterranean Ships.” *Environmental Archaeology* 14.2:163-75.

Runciman, S. 1966. *Byzantine Civilisation*. London: Edward Arnold Publishers.

Runciman, S. 1973. “Byzantine Trade and Industry.” In *The Cambridge Economic History of Europe*, Vol. 2, edited by M. M. Postan, 132-67. Cambridge, United Kingdom: Cambridge University Press.

Sanders, D. 2010. “Knowing the Ropes: The Need to Record Ropes and Rigging on Wreck-Sites and Some Techniques for Doing So.” *IJNA* 39.1:2-26.

Santamaria, C. 1984. “Le pied de mât de l’epave « E » du cap Dramont (Saint-Raphaël, Var).” *Archaeonautica* 4:107-14.

Santamaria, C. 1995. *L’Épave Dramont « E » à Saint-Raphaël (Ve siècle ap. J.-C.)*. Archaeonautica 13. Paris: CNRS Éditions.

Schilbach, E. 1970. *Byzantinische Metrologie*. Munich, Germany: C. H. Becksche Verlagsbuchhandlung.

Schweingruber, F. H. 2007. *Wood Structure and Environment*. Heidelberg, Germany: Springer.

Shaw, J. W. 1967. “A Double-Sheaved Pulley Block from Kenchreai.” *Hesperia* 36.4:389-401.

Shaw, J. W. 1972. “Greek and Roman Harborworks.” In A History of Seafaring Based on Underwater Archaeology, edited by G. F. Bass, 87-112. London: Thames & Hudson.

Shepard, J. 2008a. “Periodisation and the Contents of this Book.” In *The Cambridge History of the Byzantine Empire, c. 500-1492*, Vols. 1-2, edited by J. Shepard, 21-52. Cambridge, United Kingdom: Cambridge University Press.

Shepard, J. 2008b. “Equilibrium to Expansion (886-1025).” In *The Cambridge History of the Byzantine Empire, c. 500-1492*, Vols. 1-2, edited by J. Shepard, 493-536. Cambridge, United Kingdom: Cambridge University Press.

Sirks, B. 1991. *Food for Rome*. *The Legal Structure of the Transportation and Processing of Supplies for the Imperial Distributions in Rome and Constantinople*. Amsterdam: J. C. Gieben.

Smith, R. C. 1993. *Vanguard of Empire: Ships of Exploration in the Age of Columbus*. New York: Oxford University Press.

Sottas, J. 1939. “An Early Lateen Sail in the Mediterranean.” *Mariner’s Mirror* 25.2:229-30.

Steffy 1982a. “Reconstructing the Hull.” In *Yassı Ada: A Seventh-Century Byzantine Shipwreck*. Volume I, by G. F. Bass and F. H. van Doorninck, 65-86. College Station, TX: Texas A&M University Press.

Steffy, J. R. 1982b. "The Reconstruction of the 11th century Serçe Liman Vessel. A Preliminary Report*." IJNA* 11.1:13-34.

Steffy, J. R. 1985a. "The Kyrenia Ship: An Interim Report on its Hull Construction." *American Journal of Archaeology* 89.1:71-101, pl. 21.

Steffy, J. R. 1985b. "The Role of Three-Dimensional Research in the Kyrenia Ship Reconstruction." In *Tropis I: The First International Symposium on Ship Construction in Antiquity, Piraeus, 30 August-1 September 1985*, edited by H. Tzalas, 249-62. Athens, Greece: Hellenic Institute for the Preservation of Nautical Tradition.

Steffy, J. R. 1991. "The Mediterranean Shell to Skeleton Transition: a Northwest European Parallel?" In *Carvel Construction Technique: Skeleton-First, Shell-First; Fifth International Symposium on Boat and Ship Archaeology, Amsterdam 1988 (ISBSA 5)*, edited by R. Reinders and K. Paul, 1-9. Oxford: Oxbow Books.

Steffy, J. R. 1994. *Wooden Shipbuilding and the Interpretation of Shipwrecks*. College Station, TX: Texas A & M University Press.

Steffy, J. R. 1995. "Ancient Scantlings: The Projection and Control of Mediterranean Hull Shapes." In *Tropis III, Third International Symposium on Ship Construction in Antiquity, Athens, 24-28 August 1989*, edited by H. Tzalas, 417-28. Athens, Greece: Hellenic Institute for the Preservation of Nautical Tradition.

Steffy, J. R. 1999. "Ancient Ship Repair." In *Tropis V: Fifth International Symposium on Ship Construction in Antiquity, Nauplia, 26-28 August 1993*, edited by H.

Tzalas, 395-408. Athens, Greece: Hellenic Institute for the Preservation of Nautical Tradition.

Stieglitz, R. R. 2006. “Classical Greek Measures and the Builder’s Instruments from the Ma’agan Mikhael Shipwreck.” *AJA* 110: 195-203.

Stos-Gale, S. 2004. “Lead-Isotope Analysis of Glass, Glazes, and Some Metal Artifacts.” In *Serçe Limanı, an Eleventh-Century Shipwreck*, Volume 1: *The Ship and its Anchorage, Crew, and Passengers,* by G. F. Bass, S. D. Matthews, J. R. Steffy, and F. H. van Doorninck, 453-70. College Station, TX: Texas A&M University Press.

Stratos, A. N. 1980. “The Naval Engagement at Phoenix.” In *Charanis Studies: Essays in Honor of Peter Charanis*, edited by A. E. Laiou-Thomadakis, 229-47. New Brunswick, NJ: Rutgers University Press.

Tabak, F. 2008. *The Waning of the Mediterranean, 1550-1870: A Geohistorical Approach*. Baltimore: John Hopkins University Press.

Tammuz, O. 2005. “Mare Clausum? Sailing Seasons in the Mediterranean in Early Antiquity.” *Mediterranean Historical Review* 20.2:145-62.

Teall, J. L. 1959. “The Grain Supply of the Byzantine Empire, 330-1025.” *DOP* 13:87-139.

Teall, J. L. 1971. “The Byzantine Agricultural Tradition.” *DOP* 25:33-59.

Teall, J. L. 1977. “Byzantine Urbanism in the Military Handbooks.” In *The Medieval City*, edited by H. A. Miskimin, D. Herlihy, and A. L. Udovitch, 201-8. New Haven, CT: Yale University Press.

Throckmorton, P. and J. Throckmorton. 1973. "The Roman Wreck at Pantano Longarini." *IJNA* 2.2:243-66.

Toynbee, A. J. 1973. *Constantine Porphyrogenitus and His World*. London: Oxford University Press.

Treadgold, W. 1988. *The Byzantine Revival 780-842*. Stanford, CA: Stanford University Press.

Treadgold, W. 1997. *A History of the Byzantine State and Society.* Stanford, CA: Stanford University Press.

Treadgold, W. 2002. "The Struggle for Survival (641-780)." In *The Oxford History of Byzantium*, edited by C. Mango, 129-52. Oxford, United Kingdom: Oxford University Press.

Tsangadas, B. C. P. 1980. *The Fortifications and Defense of Constantinople*. New York: Columbia University Press.

Tsartidou, G., S. Lev-Yadun, R.-M. Albert, A. Miller-Rosen, N. Efstratiou, and S. Weiner. 2007. "The Phytolith Archaeological Record: Strengths and Weaknesses Evaluated Based on a Quantitative Modern Reference Collection from Greece." *JAS* 34: 1262-75.

Turkmenoğlu, E. 2012. "Preliminary Report on the YK 17 Shipwreck." In *Between Continents: Proceedings of the Twelfth Symposium on Boat and Ship Archaeology, Istanbul 2009 (ISBSA 12)*, edited by N. Günsenin, 121-25. Istanbul, Turkey: Zero Prodüksiyon.

Turrill, W. B. 1929. *The Plant-Life of the Balkan Peninsula. A Phytogeographical Study*. Oxford, United Kingdom: Clarendon Press.

Ucelli, G. 1950. *Le navi de Nemi*. Rome: La Libreria dello Stato.

Udell, M. 2003. "The Woodworking Tools." In *The Ma'agan Mikhael Ship: The Recovery of a 2400-Year-Old Merchantman*, edited by E. Linder, Y. Kahanov, and E. Black, Vol. 1, 203-18. Jerusalem, Israel: Israel Exploration Society and the University of Haifa.

Ulrich, R. B. 2007. *Roman Woodworking*. New Haven, CT: Yale University Press.

Unger, R. W. 1991. *The Art of Medieval Technology. Images of Noah the Shipbuilder*. New Brunswick, NJ: Rutgers University Press.

Ulrich, R. B. 2008. "Woodworking." In *The Oxford Handbook of Engineering and Technology in the Classical World*, edited by J. P. Oleson, 439-64. Oxford, United Kingdom: Oxford University Press.

Veldmeijer, A. J., and C. Zazzaro. 2008. "The 'Rope Cave' at Mersa/ Wadi Gawasis." *JARCE* 44:9-39.

Villiers, A. 1961. "Sailing with the Arabs." *Mariner's Mirror* 47.4:242-55.

Villiers, A. 1962. "Voyage in a Kuwait Boom, Part One." *Mariner's Mirror* 48.2:112-28.

Villiers, A. 2006. *Sons of Sindbad*. London: Arabian Publishing Ltd.

Vroom, J. 2005. *Byzantine to Modern Pottery in the Aegean*. Bijleveld, Netherlands: Parnassus Press.

Vryonis, S. 1962. "The Question of the Byzantine Mines." *Speculum* 37.1:1-17.

Wachsmann, S. 1995. “The 1994 INA/CMS Joint Expedition to Tantura Lagoon.” *INA Quarterly* 22.2:3-8.

Wachsmann, S. 2011. “Innovations in Ship Construction at Tantura Lagoon, Israel.” *Skyllis* 11.1:83-93.

Wachsmann, S., and Y. Kahanov. 1997. “Shipwreck Fall: The 1995 INA/CMS Joint Expedition to Tantura Lagoon, Israel.” *INA Quarterly* 24.1:3-18.

Wachsmann, S., Y. Kahanov, and J. Hall. 1997. “The Tantura B Shipwreck: The 1996 INA/CMS Joint Expedition to Tantura Lagoon.” *INA Quarterly* 24.4:13.

Waksman, S. Y. 2011. “Ceramics of the ‘Serçe Limanı Type’ and Fatimid Pottery Production in Beirut.” *Levant* 43.2:201-12.

Wallinga, H. T. 1964. “Nautika (I): The Unit Capacity for Ancient Ships.” *Mnemosyne* 17, Fasc. 1:1-40.

Ward, C. 2000. *Sacred and Secular: Ancient Egyptian Ships and Boats.* Boston: Archaeological Institute of America/University of Pennsylvania Museum.

Ward, C., and R. D. Ballard. 2004. “Deep-water Archaeological Survey in the Black Sea: 2000 Season.” *IJNA* 33.1:2-13.

Ward-Perkins, B. 2000. “Constantinople: A City and Its Ideological Territory.” In *Towns and Their Territories Between Late Antiquity and the Middle Ages*, edited by Brogiolo, G. P., N. Gauthier, and N. Christie, 325-46. Leiden, Netherlands: Brill.

Weismann, N. 1998. “The cargo-beden *Al-Khammam*.” *IJNA* 27.3:237-57.

Wendrich, W. 1999. *The World According to Basketry. An Ethno-Archaeological Interpretation of Basketry Production in Egypt*. Leiden, Netherlands: Research School of Asian, African, and Amerindian Studies (CNWS).

Whitehouse, D. 2003. "'Things That Traveled': the Surprising Case of Raw Glass." *Early Medieval Europe* 12.3:301-5.

Whitewright, J. 2007. "Roman Rigging Material from the Red Sea Port of Myos Hormos." *IJNA* 36.2:282-92.

Whitewright, J. 2009. "The Mediterranean Sail in Late Antiquity." *IJNA* 38.1:97-104.

Whitewright, J. 2011a. "Efficiency or Economics? Sail Development in the Ancient Mediterranean." In *Maritime Technology in the Ancient Economy: Ship-Design and Navigation*, edited by W. V. Harris and K. Iara, 89-102. Journal of Roman Archaeology Supplementary Series No. 84. Portsmouth, RI: Journal of Roman Archaeology.

Whitewright, J. 2011b. "The Potential Performance of Ancient Mediterranean Sailing Rigs." *IJNA* 40.1:2-17.

Whitewright, J. 2012. "Technological Continuity and Change: The Lateen Sail of the Medieval Mediterranean." *Al-Masaq: Islam and the Medieval Mediterranean* 24.1:1-19.

Whittow, M. 1996. *The Making of Byzantium, 600-1025*. Berkeley, CA: University of California Press.

Whittow, M. 2008. "The Middle Byzantine Economy, (600-1204)." In *The Cambridge History of the Byzantine Empire, c. 500-1492*, Vol. 1, edited by J. Shepard, 465-92. Cambridge, United Kingdom: Cambridge University Press.

Wickham, C. 2004. "The Mediterranean Around 800: On the Brink of the Second Trade Cycle." *DOP* 58:161-74.

Wild, J. P. 1970. *Textile Manufacture in the Northern Roman Provinces*. Cambridge, United Kingdom: Cambridge University Press.

Wild, F. C., and J. P. Wild. 2001. "Sails from the Roman Port of Berenike, Egypt." *IJNA* 30.2:211-20.

Wortley, J. 1999. "The Byzantine Component of the Relic-Hoard of Constantinople." *GRBS* 40.4:353-78.

Ximenes, S. 1976. "Étude préliminaire de l'épave sarrasine du rocher de l'Estéou." *Cahiers d'archeologie* 5:139-50.

Yardeni, A. 1994. "Maritime Trade and Royal Accountancy in an Erased Customs Scroll from 475 B.C.E. on the Ahiqar Scroll from Elephantine." *BASOR* 293:67-78.

Zafiropoulou, D., ed. 1998. *Sailing on the Seas of Byzantium*. Translated by D. Turner. Athens, Greece: Ministry of Culture, Directorate of Byzantine and Post-Byzantine Monuments.

APPENDIX A

HULL COEFFICIENTS[949]

Displacement at load waterline (LWL-estimated): **21.45 long tons/ 22.24 tonnes**

Freeboard at LWL: **0.97 m**

Estimated tonnage: **12-13 long tons** (approximately 950-1,000 *modioi*)[950]

Calculated tonnage [length of keel x molded beam x depth of hold]: = **12.1 long tons**[951]

Length/beam ratio (topside): 14.63 m/ 3.40 m = **4.30:1**

Length/beam ration (waterline): 12.18 m/ 2.82 m = **4.32:1**

Waterplane area: **20.4 m²**

Waterplane coefficient (Area of Waterplane/ Length at Load Waterline x Beam at Load Waterline): **0.59**

Midship coefficient (Area of Midship area to LWL/ Beam at LWL x Draft to LWL): **0.76**

Block coefficient (Volume of Displacement at LWL/ Length x Beam x Draft at LWL): **0.76**

Prismatic coefficient (Volume of Displacement at LWL/ Length at LWL x Area of maximum section at LWL): **0.91**

[949] Formulas for the hull coefficients are taken from Gillmer and Johnson (1982, 42-5).
[950] A Byzantine *modios* used as a dry measure in the Middle Byzantine period is equivalent to 12.8 kg or 17.084 liters (Schilbach 1970, 96).
[951] Metric values were converted to imperial measurements for this calculation, based on the common formula for calculating tonnage (see Bass et al. 2004, 169). One long ton is equals 2,240 pounds or 1.01605 tonnes/ metric tons (Gillmer and Johnson 1982, 40).

APPENDIX B

GLOSSARY OF NAUTICAL TERMS[952]

Adze: An axe-like tool with its blade at right angles to the handle, used for shaping and dressing wood.

Aft: The area of a vessel's hull towards the stern.

Amidships: The middle of a vessel, either longitudinally or transversely.

Apron: A curved piece of timber fixed to the after surface of the stem or to the top of the forward end of the keel and the after surface of the stem; an internal stempost.

Beam: A timber mounted athwartships to support decks and provide lateral strength.

Bevel: The fore-and-aft angle or curvature of an inner or outer frame surface.

Bilge: The area of the hull's bottom on which it would rest if grounded; generally, the outer end of the floor.

Bilge Keel: A secondary keel placed beneath the bilge or at the outer end of the floor.

Bolt: A cylindrical metal pin used to fasten ship's timbers together.

Bow drill: A device with a hollow handle in which a spindle rotates: the spindle is connected to a drum, around which a cord is wrapped and run back and forth by means of a bow to rotate the drill bit.

Breadth: The width of a hull; sometimes called beam, which is technically the length of the main beam.

[952] Terms in the glossary are adapted or taken directly from Steffy 1994, p.267-98, and Lever 1998 unless otherwise noted or defined in the text of the dissertation.

Bulkhead: A vertical partition, either fore-and-aft or athwartships.

Bulwark: The side of a vessel above its upper deck.

Burden: The cargo capacity of a vessel.

Butt joint/Butt scarf: The union of two planks or timbers whose ends were cut perpendicularly to their lengths.

Caprail: A timber attached to the top of a vessel's frames.

Careen: To deliberately list a vessel so that part of its bottom was exposed for caulking, cleaning, repairing, etc.

Ceiling planking: The internal planking of a vessel.

Chamfer: The flat, sloping surface created by slicing off the edge of a timber.

Chine: The angular junction of the bottom of and side of a vessel; usually found on flat-bottomed hulls, or those with little deadrise.

Cleat: 1) Pieces of wood used belay or tie ropes at a specific point in the ship. 2) Timbers used as temporary framing in the construction of a hull, particularly in shell-first and bottom-based construction (see Hocker 2004b).

Clench: To secure a nail or bolt by bending or flattening its projecting end over the surface of it last penetrated; a nail whose tip and shaft were both clenched is said to be *double-clenched*, as in the fastening of ancient ship frames and planks.

Clinker-building: A vessel constructed so that its outer planking overlaps, and is fastened to, the plank immediately below it using rivets or nails clenched over washers called roves. Clinker building was a standard technique in Northern

European shipbuilding in the early medieval period. Ships whose overlapping planks are fastened together with clenched nails are called *lapstrake* hulls.

Coak: A rectangular or cylindrical pin let into the ends or seams of timbers about to be joined in order to align or strengthen the union. In Middle Byzantine shipbuilding of the ninth and tenth centuries, cylindrical coaks are used to edge-fasten the lower hull planking in ships' hulls.

Compass Timber: Naturally-curved timber used for frames and the construction of the ends of a hull.

Deadrise: The amount of elevation, or rising, of the floor above the horizontal plane; the difference between the height of the bilge and the height of the keel rabbet.

Dhow: A generic term for indigenous sailed vessels of the Arabian Peninsula, especially the Persian Gulf, and east African coast. Many varieties of dhows have been used in the Indian Ocean since antiquity (see Agius 2002, 31-47).

Diagonal scarf: An angular junction of two planks or timbers; a common method of joining hull planks in ancient and early medieval Mediterranean ships.

Dowel: A cylindrical piece of wood (of constant diameter) used to align two members by being sunk into each. A cylindrical coak. Unlike treenails and pegs, dowels serve an alignment function only, additional fasteners being necessary to prevent separation of the joint. *[Note: the term 'dowel' is often used interchangeably with 'coak' in reports on Byzantine shipwrecks. The term 'coaks' is used in this study based on the fact that a) the coaks used in the Yenikapı ships are rarely of* *constant diameter and, b) coaks used in the Yenikapı ships' hulls function as fasteners and are not used only to align timbers.*

Draft: The depth to which a hull is immersed.

Drawknife: A knife with two handles mounted at right angles to the blade; drawknives are used for shaping and beveling.

Dropstrake: A strake of planking that is discontinued near the bow or stern because of decreasing hull surface area. A central stealer.

Dubbing: Trimming of a timber's surface with an adze.

Dunnage: Brushwood, scrap wood, or other loose material laid in the hold to protect the cargo from water damage or prevent it from shifting, or to protect the ceiling from abrasion.

Edge fastener: A generic term for any wooden fastener (either tenons or coaks) driven into the edges of hull planks to fasten them together.

False keel: A plank, timber, or timbers attached to the bottom of the keel to protect it in the event of grounding or hauling.

Floor timber: A frame timber that crossed the keel and spanned the bottom; the central piece of a compound frame.

Forelock bolt: An iron bolt with a head on one end and a narrow slot at the other; secured by placing a washer over its protruding end and driving a flat wedge, called a forelock, into the slot.

Frame: A transverse timber, or line or assembly of timbers, that describe the body shape of a vessel and to which the planking and ceiling were fastened.

Freeboard: The distance between the waterline and upper deck or caprail.

Futtock: A frame timber other than a floor timber, half-frame, or top timber; one of the middle pieces of a frame.

Galley: 1) A seagoing vessel propelled primarily by oars, but usually one that also could be sailed when necessary. 2) A vessel's kitchen. The Byzantines used several terms to refer to rowed vessels, depending on their type and the time period, including *dromons*, 'runner,' the main warship type of the Byzantine navy, and *galeai*, a type of light multipurpose galley.

Garboard strake: The strake of planking next to the keel; the lowest plank.

Graving piece: A wooden patch, or insert, let into a damaged or rotted plank.

Half-frame: A frame whose heel or inboard end begins at or near one side of the keel or deadwood and spanned part or all of that side of the hull. Half-frames were usually used in pairs.

Halyard: Ropes used to hoist a yard and sail.

Hog: The strain on a hull that causes its ends to droop.

Hold: The interior of a hull.

Hood end: The end of a plank that fit into the stem- and sternpost rabbets.

Hook scarf: The union of two timbers whose angular ends are offset to lock the joint. Hook scarfs are sometimes locked with wedges, or keys, ('keyed hook scarfs') as is the case of keel scarfs in YK 14 and many other ancient and medieval ships.

Inboard: The end or edge of a timber closer to the vessel's keel.

Keel: The main longitudinal timber of most hulls, upon which the frames and other timbers of the hull were mounted; the backbone of the hull.

Keelson: An internal longitudinal timber or line of timbers, mounted atop the frames along the centerline of the keel that provided additional longitudinal strength to the bottom of the hull; an internal keel.

Lateen rig: A fore-and-aft rig consisting of a large triangular sail hung from a canted yard. The s**ettee or Arab lateen rig** is a variation on the lateen, with a short luff, or section perpendicular to the bottom of the sail, at the forward end of the yard.

Limber hole: Apertures cut in the bottom surfaces of frames over, or on either side of, the keel to allow water to drain into the sump.

Luting: A term used to describe the caulking of lapstrake and clinker-built hulls. In most cases, animal hair, wool, or moss was soaked in pitch or resin and laid in a luting cove, which was cut in the lower inside surface of the overlapping plank. Luting generally refers to caulking inserted between two hull members before they were assembled, as opposed to driven caulking. The term is also applied to any plastic material used between two adjacent members.

Mast partner: A through-beam used to steady and support a mast. The mast was typically lashed to the mast partner.

Mast step: A mortise cut into a block of wood positioned over the keel for the heel of the mast.

Midship: A general term for the widest section of the hull.

Midship frame: The broadest frame in the hull; the frame representing the midship shape on the body plan.

Molded dimension: The vertical surfaces (the sides) of keels, the fore-and-aft sides of the posts, the vertical or athwartships surfaces of the frames, etc. Normally, timbers are expressed in sided and molded dimensions, while planks and wales are listed in thicknesses and widths. Molded and sided dimensions are used because of the changing orientation of timbers, such as frames, where "thick" and "wide" or "height" and "depth" may become confusing. The various dimensions of timbers are seen from the sheer and body views of construction plans; the dimensions determined by molds.

Mortise and tenon joint: A union of planks and timbers by which a projecting piece (tenon) was fitted into one or more cavities (mortises) of corresponding size. In pegged mortise-and-tenon joinery, pegs driven through the thickness of the hull planking were used to lock the tenons in place, while pegs were not used in unpegged mortise-and-tenon joinery, a construction method used in the hulls of some Late Roman and early Byzantine ships.

Outboard: The end or edge of a hull timber closer to the port or starboard sides of a vessel's hull.

Pilot hole: A hole drilled to aid in the driving of a nail.

Pitch: A dark, sticky substance used in caulking seams or spread over the inner and outer faces of hulls as waterproofing and as protection against some forms of marine life. Pitches were variously derived from the resins of certain evergreen trees; from bitumens, such as mineral pitches; or from the distillation of coal tar, wood tar, etc. Some authors distinguish between pitch and tar based on collection and refinement methods (see Chapter VI).

Planking: The outer lining, or shell, of a hull.

Plank edge: The inboard or outboard thickness of a hull plank.

Quarter-rudder: A timber or assembly of timbers that could be rotated on an axis to steer a vessel. Quarter rudders were hung from the stern quarters of ancient and early medieval Mediterranean ships and lashed to through-beams and other support timbers in the aft area of the hull.

Rabbet: A groove or cut made in a piece of timber in such a way that the edges of another piece could be fit into it to make a tight joint. Generally, the term refers to the grooves cut in the sides of a keel, stem, and sternpost, into which the garboards and hood ends of the outer planking were seated.

Running rigging: Rigging used primarily to manipulate the yards and sails of a ship.

Scarf: An overlapping joint used to connect two timbers or planks without increasing their dimensions. Common types used in ancient and medieval Mediterranean shipbuilding include elongated diagonal, three-plane, and **S-scarfs,** shorter **butt scarfs**, and **keyed-hook scarfs**.

Score mark: An incised mark, cut or scored into the surface of a timber, used to delineate a particular area or location during the assembly of a ship. In ancient and medieval Mediterranean ships, score marks were frequently used to mark the intended locations of frames and edge fasteners.

Shroud: A rope support used to steady a mast to the side of a hull. This type of line is normally standing rigging on most vessel types, but a lateen or settee rig uses running or moveable shrouds.

Sided dimension: See Molded Dimension.

Spar: A timber making up part of a yard.

Square rig: A rig in which most or all of the yards from which the sails hang are athwartships or perpendicular to the longitudinal axis of the ship. **Fore-and-aft rigs**, such as the lateen and settee rigs, have yards oriented roughly parallel to the longitudinal axis of the ship.

Stanchion: An upright support post.

Standing rigging: Rigging used to support the masts of a ship.

Stealer: A short plank inserted between two strakes of planking so that the regular strakes did not have to be made too wide; usually located at the bow or stern ends of bottom or lower side strakes.

Stempost: A vertical or upward-curving timber, scarfed to the keel or central plank at its lower end, into which the two sides of the bow are joined.

Stemson: A curved timber mounted on the inner surface of the apron; usually, the forward and upper extension of the keelson Stemsons and sternsoms are sometimes referred to as 'central longitudinal timbers' in reports on Roman and Byzantine shipwrecks.

Sternpost: A vertical or upward-curving timber or scarfed into the after end of the keel.

Sternson: A curved timber joining the keelson and inner sternpost; usually an extension of keelson, mounted on top of the deadwood.

Stocks: A structure supporting a vessel under construction or repair.

Strake: A continuous row of planks, running from bow to stern.

Stringer: A general term describing the longitudinal timbers fixed to the inside surfaces of the frames.

Sump: The cavity or compartment in the bottom of the hull, usually near amidships, where bilge water collected and from which it was pumped out or bailed.

Tabernacle: A timber assembly or housing that supported a mast or post at deck level.

Tacking and **Wearing:** A sailing maneuver used to change direction when sailing into the direction of the wind. **Wearing** involves the steering of a ship to windward by turning a ship away from the wind, while **tacking** involves a turn into the wind that uses the ship's momentum to set the vessel at a similar angle traveling in the opposite windward direction.

Tenon: A wooden projection cut from the end of a timber or a separate wooden piece that was shaped to fit a corresponding mortise. See **Mortise-and-tenon joint**.

Through-beam: An athwartships timber that extended through and beyond the outer hull planking.

Top timber: The uppermost member of a frame, or frames used to support the upper section of the sides of a hull to the caprail.

Treenail: A round or multi-sided piece of hardwood, driven through planks and timbers to connect them. Treenails were employed most frequently in fastening planking to frames and in the scarfing of timbers. They were used in a variety of forms: with expanding wedges or nails in their ends, with tapered or square heads on their exterior ends, or completely unwedged and unheaded. When immersed, treenails swelled to make a tight fit.

Turn of the bilge: The outboard part of the lower hull where the bottom curved toward the side.

Wale: A thick strake of planking located along the side of a vessel for the purpose of girding and stiffening the outer hull.

Yard: A single or composite timber pole from which a sail hangs.